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TWIST DRILLS AND DRILLING PROCESSES

BY

C. H. KAHNG

December 1976

TECHNICAL REPORT

U.S. ARMY ARMAMENT COMMAND

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This report brings together in one volume the vast information on drills and drilling processes published in numerous journals and technical papers. A review of more than 800 articles was conducted; the result being a collection of 271 of the most valuable articles in the field of drilling from worldwide publications dated 1896 to present. A brief abstract of each article is given along with important illustrations and tables. This systematic survey of

20. ABSTRACT (continued)

literature on twist drills and drilling will be useful to those who wish to study the essential research results and stages of development in this field. (U) (C. H. Kahng)

FOREWORD

This report was prepared by Prof. C. H. Kahng of the Michigan Technological University, Houghton, Michigan in compliance with Contract No. DAAA09-74-C-2062. This work was performed for the Research Directorate, GEN Thomas J. Rodman Laboratory, Rock Island, Illinois, with Mr. R. A. Kirschbaum as Project Engineer.

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PREFACE

Because of the numerous physical variables in drills and drilling, and the indefinite interrelationships of these variables, the evolvement of drills and drilling continues to be an art. Consequently, for all of the related empirical testing, and even the scientific analyses, of drill wear and performance, an understanding of this evolvement is critically necessary to extend the state-of-the-art. However, even though thousands of articles related to drills and drilling processes have been published in numerous journals and technical papers, no one has previously attempted to bring together this information in one complete volume. Furthermore, no similar volume is known to bring together such information from as many different languages.

Therefore, in consideration of the need for realizing the many variables encountered in developing and applying a better understanding of this subject, the author has made and presented a systematic survey of literature which will be both informative and useful to those people who wish to study and apply, in a short period of time, the essential stages and results of development in this particular field. From this standpoint, a review of more than 800 articles was conducted in the field of drilling from worldwide publications dated 1896 to present. A brief abstract of each article is given with important illustrations and tables. The articles are presented in the following format:

1. Author's Name

2. Title of Article

3. Publication Source

4. Abstract of Article

The literature is arranged in chronological order, and the number of each article appears in parentheses on the upper right-hand corner of the page. Briefly, the abstracts present both general and specific scientific, engineering and manufacturing information, discussions and data. Drills are presented by type, geometry, size and material, with information related to manufacturing and resharpening. Applications, practices, methods, techniques and controls for drilling are presented with mechanics of chip formation, wear, stresses, machine tools, fixtures and bushings. Research studies are presented with

discussions of theory and practices from scientific, engineering and shop levels; and testing is reviewed in terms of equipment, instruments, measurement and analyses. Interrelationships of the foregoing are discussed in terms of performance, machinability, accuracy and economics, with related operational parameters such as speeds, feeds, coolants and elements of drill geometries.

1. ANONYMOUS

2. TWIST DRILLS WITH TUBES FOR LUBRICANT

3. AMERICAN MACHINIST, 1896, Vol. July 16, pp. 676

4. An example of a twist drill with tubes for delivering lubricant to the cutting edge. The tubes are soldered in grooves milled in the lands of the drill.

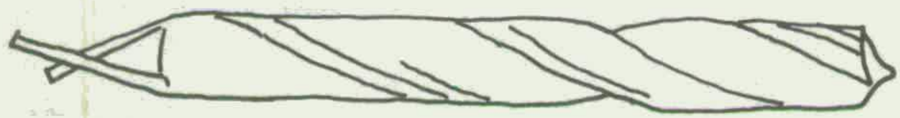


FIG. 1. Twist drill with tubes

1. LOBBEN, P.

2. SPEED OF TWIST DRILLS

3. AMERICAN MACHINIST, 1896, Vol. Aug. 6, pp. 748-749

4. The speed of twist drills cannot be based on the drill diameter as a rule but is dependent on how fast the heat generated in drilling can be dissipated.

   If the size of the workpiece is large compared to the drill, the speed may be increased since a large body of metal carries the heat away more quickly.

   When the size of the workpiece is small, arranging the jigs and fixtures so that there is again plenty of metal surrounding the piece to be drilled, the heat will be dissipated faster and the drill speed increased.

1. ANONYMOUS

2. SPECIAL DRILLS WITH LUBRICANT TUBES

3. AMERICAN MACHINIST, 1896, Sept.17, pp. 870

4. An example of twist drills with lubrication tubes soldered into grooves milled in the drill lands. The lubricant is supplied through a hole in the drill shank.

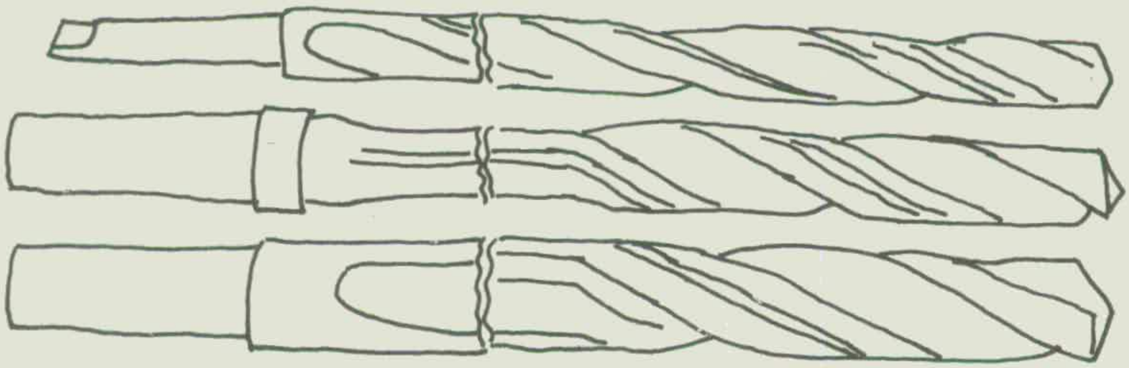


FIG. 1. Oil hole drills

1. LOBBEN, P.

2. HIGH SPEED DRILLING FOR DEEP HOLES

3. AMERICAN MACHINIST, 1896, December 3, pp. 1135-1136

4. When drilling a 12 in. deep hole in a drop forged mild steel, a cutting speed of 1000 rpm (212 fpm) and a feed rate of 0.0008 ipr were used.

   A drill with an oil groove and a point configuration as shown in Fig. 1 was used.

   The drill is held stationary while the workpiece rotates.

   About 2 gallons per minute of lard oil were pumped through the drill to cool it and assist in removing the chips.

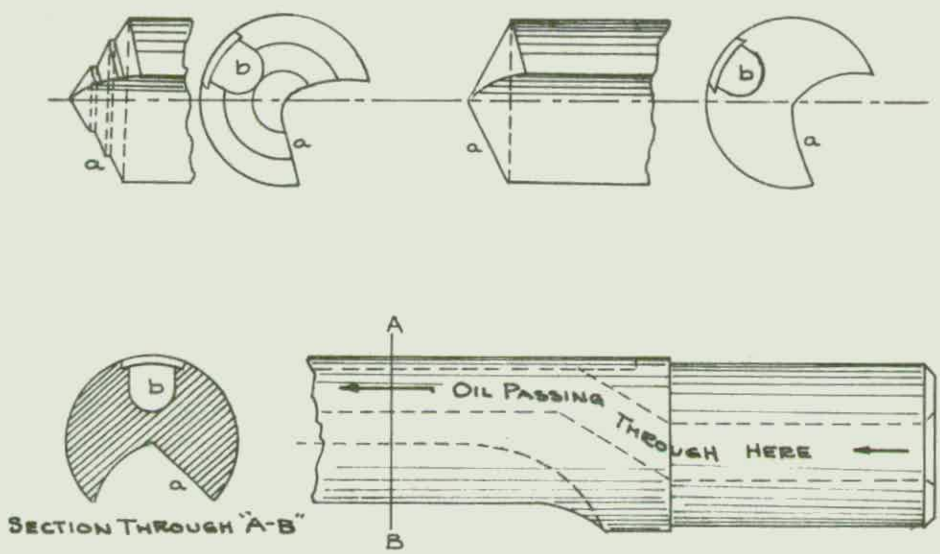


FIG. 1. Oil hole drills

1. ANONYMOUS

2. IMPROVING THE TWIST DRILL

3. AMERICAN MACHINIST, Dec. 17, 1896, pp. 1179-1180

4. The "groove" on each side of the drill is made up of two or more curves with an angular projection. This is shown in Fig. 1.

   The drill with this section produces two or more separate chips for each cutting lip.

   The increased tensile strength of the drill at the section with the angular projection allows the drill to be made thinner at the center with the result of easier cutting.

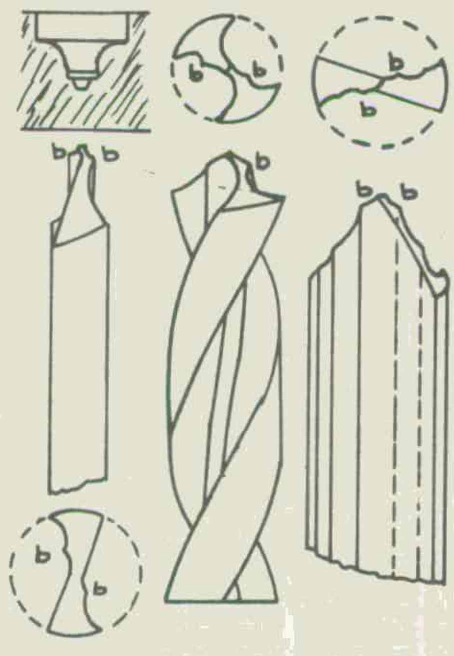


FIG. 1. Different drill geometries

1. SWEET, J. E.

2. FLAT AND TWIST DRILLS

3. AMERICAN MACHINIST, 1897, Feb. 4, pp. 29

4. The author states that the conical shape of the drill point does not "nose" its way into iron as the wedge shaped point of a flat drill and as a result, heats up and goes "slow".

   With the faces of the cutting lips ground plumb or sloping back a twist drill is as efficient at drilling brass or thin pieces as a flat drill.

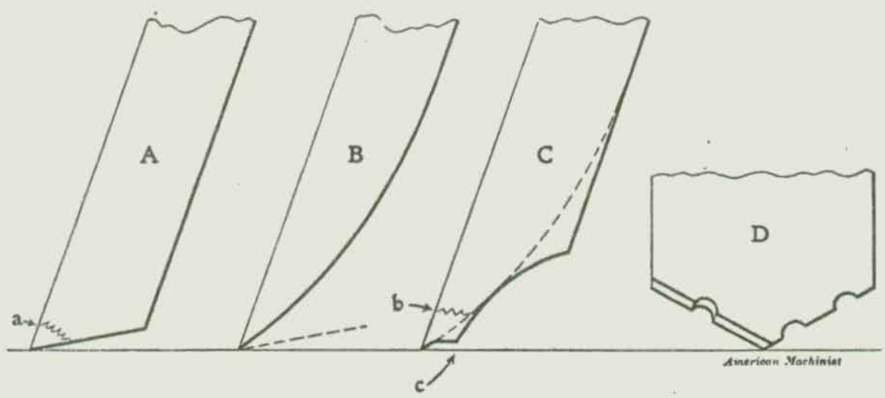


FIG. 1. Grinding twist drills

1. ANONYMOUS

2. AN IMPROVED TWIST DRILL

3. AMERICAN MACHINIST, 1897, March 4, pp. 172

4. An early version of an oil-hole twist drill is shown in Fig. 1. Grooves are formed on the drill land and a dovetail is formed at the top of the groove. A strip of brass is inserted into the dovetail to form a channel for the fluid. This method has the advantage that less material must be removed from the drill for a given oil-carrying capacity.

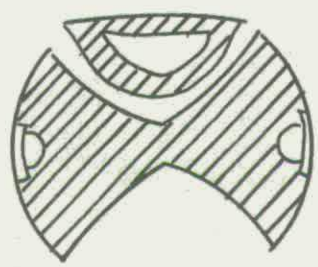


FIG. 1. Oil hole twist drill

1. SHARP, L. C.

2. TWIST DRILLS AND FLAT DRILLS

3. AMERICAN MACHINIST, 1897, March 18, pp. 214-215

4. When drilling large holes a small drill is used first and then the hole is drilled to size with a flat drill. The small drill is less liable to "run" and with the larger drill following the predrilled hole more accurate hole location is obtained.

   With the twist drill being so thick on the point, the drill doesn't have the chance to punch its way into the material nor the speed to cut well.

1. ANONYMOUS

2. SOME RECORDS OF DRILL TESTING

3. AMERICAN MACHINIST, 1897, March

4. Tests were run on 5/16" diameter drills running at a speed of 254 rpm, a feed rate of 0.018 ipr in drilling a "good" grade of soft steel 1 in. thick.

   Milled and forged drills were tested with the drills that were milled producing 12 to 15 holes and the forged drills 4 to 12 holes.

   The geometry and hardness of the drills were varied with no appreciable changes although the drills that had been milled always out-performed those that had been forged.

1. SWIFT, T.

2. THE DIVIDED CHIP OF THE TWIST DRILL

3. AMERICAN MACHINIST, 1897, April 29, pp. 330-331

4. A previously proposed point geometry for a twist drill is discussed. The cutting edges are divided into four nearly equal sections. There are two projecting cutting portions and two recessed sections that do not cut. The radial distance of the projecting portion of one cutting edge is the same as the radial distance of the recessed portions on the other cutting edge.

   This geometry was proposed to break or divide the chips.

   It is stated that if free and easy cutting is desired the cutting edges must be straight.

1. ANONYMOUS

2. THE LIMITING SIZE OF A TWIST DRILL

3. AMERICAN MACHINIST, 1899, pp. 1101-1102

4. The force required to "push" a large twist drill through solid steel or cast iron is needed to overcome the resistance of the central portion of the drill. This resistance is partly overcome by the tendency of the outer portions of the lips to draw in or feed themselves.

   This tendency of the lips to draw themselves in was determined from the fact that enlarging a hole with a twist drill requires little force to do so, and from experiments conducted by L. P. Breckenridge in 1888.

   Utilizing the dynamometer shown in Fig. 1, Prof. Breckenridge determined the maximum pressure to start a drill and the maximum pressure when drilling with the full diameter. The forces determined are shown in Table 1.

   The difference between the starting pressure and the pressure with the full drill diameter is taken as the drawing-in force of the outer portion of the lips. In the case of the 1¼ in. diameter drill this is seen to be 800 lbs.

   For drilling holes above 1½ in. in diameter it was advised to first drill the holes with a twist drill and then use the special tool shown in Fig. 2.

TABLE 1

THRUST

Diam. of Drill Inches.	Maximum Pressure on Drill while Drilling at Start.	Maximum Pressure on Drill while Drilling with Full Diameter of Drill.
1/4	400 lbs.	350- 400 lbs.
1/2	900 lbs.	800- 900 lbs.
3/4	1,100 lbs.	800- 900 lbs.
1	1,450 lbs.	1,000-1,150 lbs.
1 1/4	1,800 lbs.	1,000-1,150 lbs.

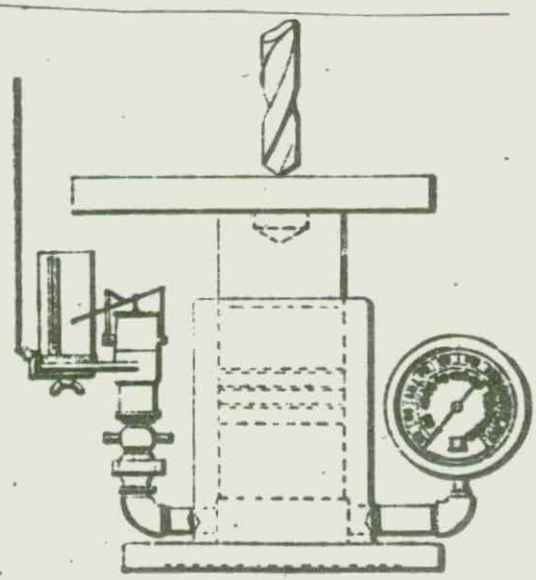


FIG. 1. Apparatus for making drilling diagram

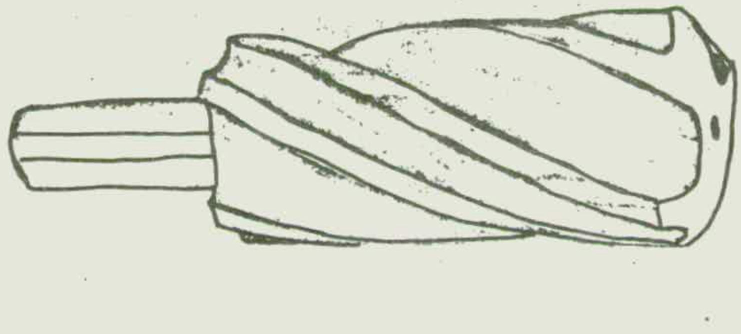


FIG. 2. A four-lipped drill

1. RIDDERHOF, C.

2. TWIST DRILLS

3. AMERICAN MACHINIST, 1903, Jan. 1

4. The author states the importance of grinding drills by machine to obtain equal length and angle of cutting lips and proper clearance.

   Most drills are broken on breakthrough due to severe shearing stresses and torsional strains that tend to unwind the drill.

   In drilling deep holes, it was recommended that one lip be ground slightly longer than the other so the drill doesn't bind.

1. BIRD, W. W. and FAIRFIELD, H. P.

2. A TWIST DRILL DYNAMOMETER

3. TRANS. ASME, 1905, Vol. 26, pp. 355-366

4. The torque and thrust were determined on this dynamometer by mechanical and hydraulic means. The thrust was recorded on a card on a rotating drum that had the force transmitted to it through a series of cylinders filled with oil and a piston arrangement.

   The torque was determined by restraining the chuck holding the workpiece and recording the twisting moment on another indicator.

   The results of the experiments show that the thrust increases rapidly with feed rate while torque does not increase as rapidly with feed rate as the thrust. This is shown in Figs. 1 and 2.

   The point angle of the drill was varied 74 and 140 degrees. It was found that the thrust increased as the point angle increased although the torque remained practically constant.

   When a pilot hole was drilled in the specimen 0.10 in. in diameter and then a 5/8-in. diameter drill was used, the thrust force was reduced by one half over that when no pilot hole was used.

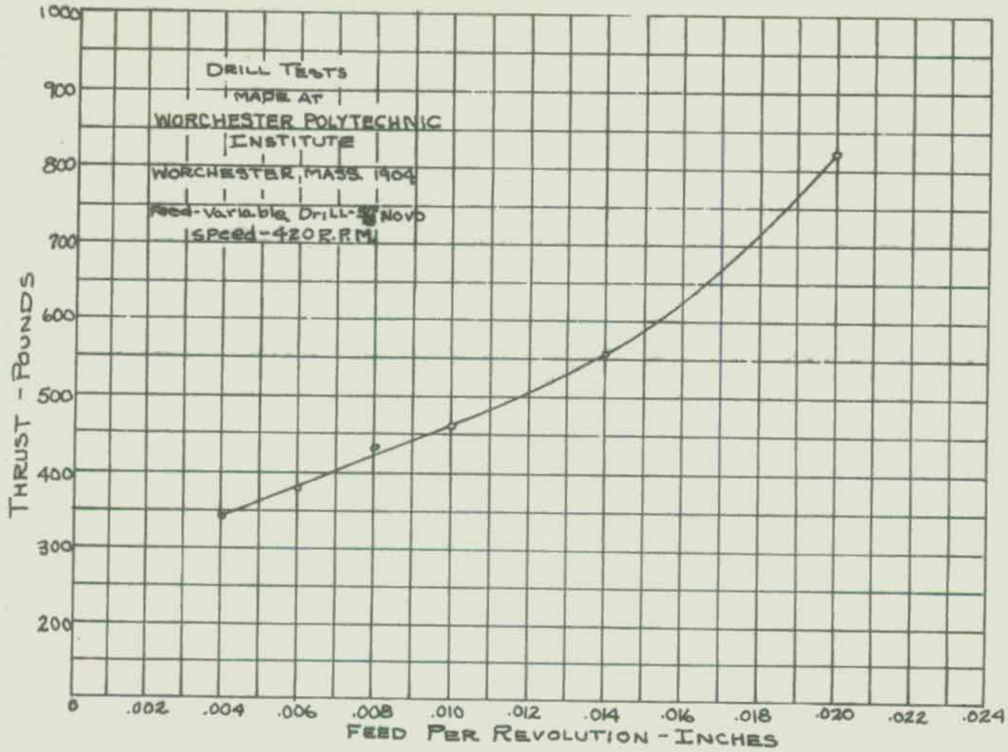


FIG. 1. Influence of feed rate on thrust

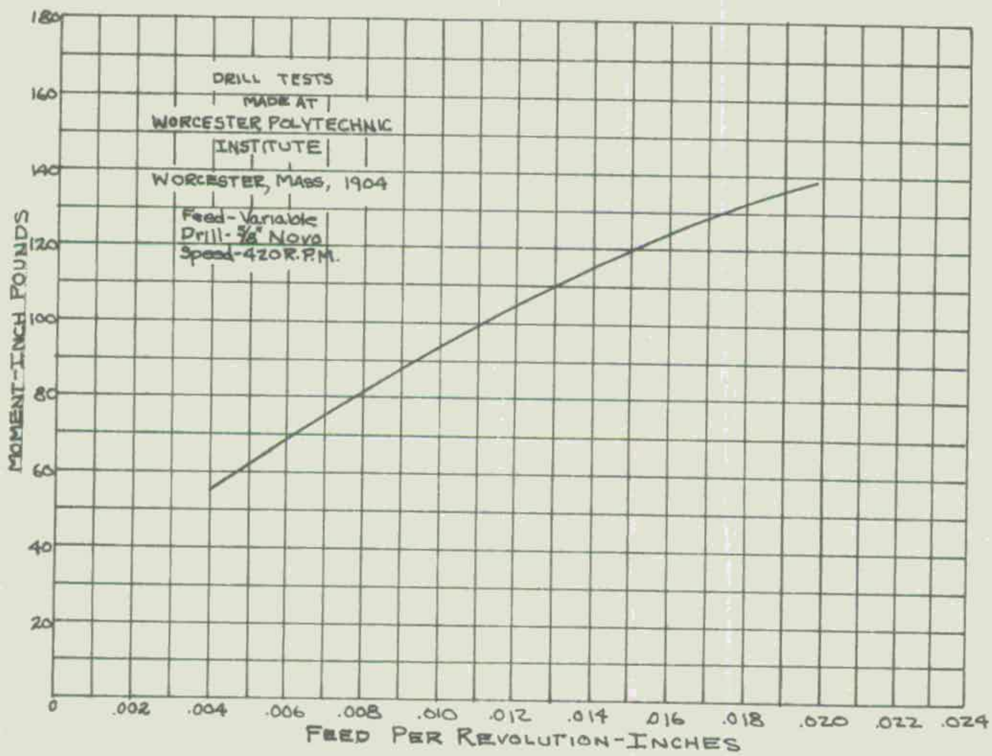


FIG. 2. Influence of feed rate on torque

1. HESS, H.

2. THE THRUST OF TWIST DRILLS

3. AMERICAN MACHINIST, 1907, Vol. 30, No. 17, pp. 598

4. The author has developed a formula for thrust from experiments by Frary and Adams for drilling cast iron.

   The relationship is: $T = (D + 12)\ (2000\ f + 20) - 250$ where T = thrust in pounds, f = feed in ipr, and D = drill diameter in units of 1/16 inch.

1. COLVIN, FRED H.

2. THE MAKING AND TESTING OF TWIST DRILLS

3. AMERICAN MACHINIST, 1907, Vol. 30, No. 39, pp. 433-440

4. The author discusses the steps in manufacturing and testing of twist drills.

   The drills were tested after hardening by sampling a heat, breaking the drills and observing the fracture. If the fracture is "all right" several more drills are subjected to a drilling test.

   In the drilling test the drills are tested to destruction. The work material is billets high in carbon and manganese. Carbon drills over ½-in. diameter can be "counted" on to drill 10 to 12 inches of the billets at cutting speeds of 30 fpm, feed rates of 0.01 ipr and cutting dry. High speed drills are tested at speeds of 50-60 fpm, feed rates of 0.005 to 0.012 ipr using soda water as a lubricant. These drills are expected to cut 50 inches in the billets.

   Most of the trouble with twist drills comes from improper grinding. It is recommended that the clearance of the cutting edge should be 12-15 degrees and the chisel edge angle be 135°.

   It was also recommended that drills be ground by hand since most machines are improperly used with the wrong clearance being ground.

1. FRARY, C. S. and ADAMS, E. A.

2. TEST OF THE POWER REQUIRED TO DRIVE TWIST DRILLS

3. AMERICAN MACHINIST, 1907, Feb. 14, pp. 210-212

4. A dynamometer used for conducting these tests consisted of a hollow piston with a round top to form a table. This piston was fitted in a cylinder filled with heavy cylinder oil with a pressure gage.

   To measure the torque a steel band was attached to the large top of the piston and connected to an indicator spring. The movement of the indicator drum was obtained by passing a cord over a pulley which was attached to the carriage of the spindle and then fastening the end to an arm projecting from the dynamometer.

   Tests were run to determine the torque and thrust required to drill cast iron. The drills were 1/2 to 7/8 inches in diameter with point angles varying from 37½ to 75 degrees.

   The author's findings are:

   With a constant speed the thrust was proportional to feed and drill diameter.

   With a point angle of 45° the thrust was lowest. Figs. 1 and 2 show the relationships of torque and thrust to point angle and feed rate.

   The torque is not related to point angle although it is nearly proportional to the feed rate.

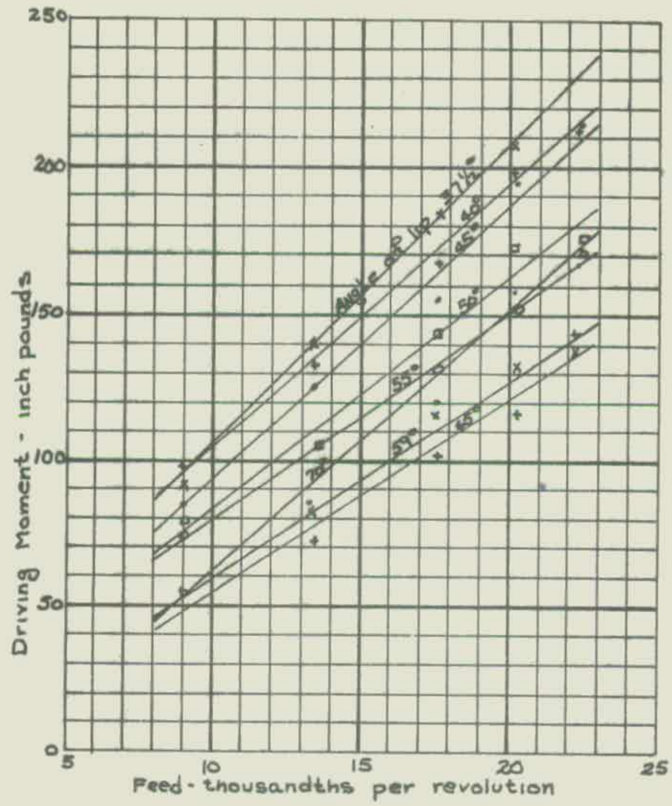


FIG. 1. Relationship of torque to point angle and feed rate. 5/8" diam. drill, 450 rpm

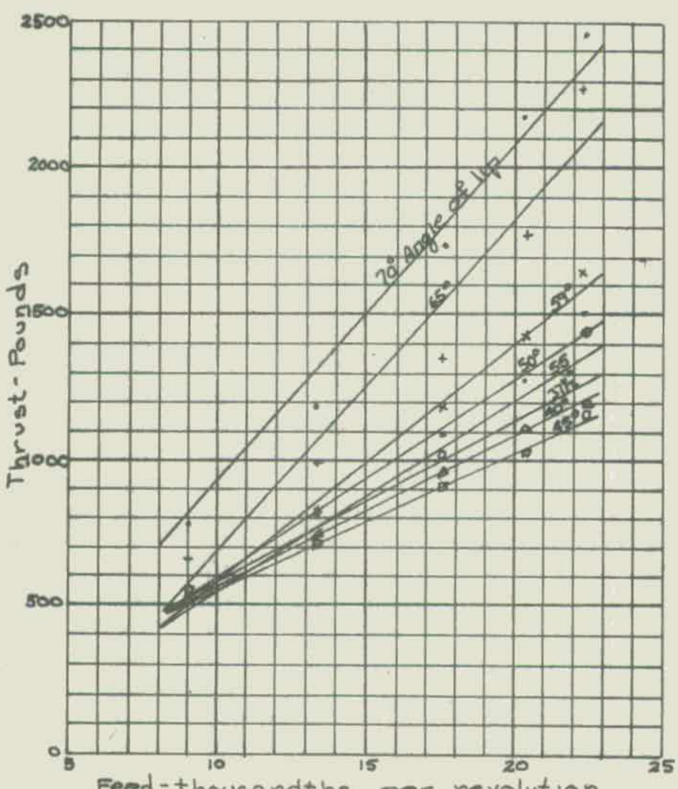


FIG. 2. Relationship of thrust to point angle and feed rate. 5/8" diam. drill, 450 rpm

1. SMITH, D. and POLIAKOFF, R.

2. EXPERIMENTS UPON THE FORCES ACTING ON TWIST DRILLS WHEN OPERATING ON CAST IRON

3. PROCEEDINGS OF THE INSTITUTION OF MECHANICAL ENGINEERS, 1909, pp. 315-415

4. The authors performed a series of experiments in drilling cast iron and steel.

   Expressions for determining the torque (T) and thrust (P) when drilling cast iron and steel were determined and are given as:

   Cast Iron
   $T = 740\ d^{1.8}\ t^{0.7}$ $\quad$ $P = 35{,}500\ d^{0.7} t^{0.75}$

   Steel
   $T = 1640\ d^{1.8}\ t^{0.7}$ $\quad$ $P = 35{,}500\ d^{0.7}\ t^{0.6}$

   T = Torque (lb-ft)
   P = Thrust (lbs)
   d = drill diameter (inches)
   t - feed rate (ipr)

   By drilling a pilot hole of a diameter that equalled the width of the chisel edge, the effect of the chisel edge on torque and thrust was studied. It was found that torque was not affected but that the thrust was reduced by 20 percent. The thrust equations were determined to be:

   Cast Iron
   $P = 12{,}600\ d^{o.7}\ t^{0.6}$

   Steel
   $P = 27{,}000\ d^{0.73}\ t^{0.6}$

   Increasing the feed rate or drill diameter was more economical than increasing the drilling speed.

   If the drill is ground so that one cutting lip does all the work, the cutting pressure, or thrust, is the same as that obtained by doubling the feed rate.

   If the point angle is increased beyond 120 degrees the torque is reduced and the thrust increased. The opposite holds if the point angle is reduced below 120 degrees.

1. NORRIS, E. R.

2. HIGH SPEED DRILL TESTS

3. AMERICAN MACHINIST, 1911, April 20, pp. 719-723

4. Endurance tests were run on twisted milled fluted and forged fluted high speed steel drills in drilling steel and cast iron.

   It was found that the flat twisted drills required more power to drive than the milled flute drills.

   It was found that the power required to remove one cubic inch of cast iron per minute increased linearly while that for steel did not. It was thought that this was due to extra power being required to curl or bend the steel chips.

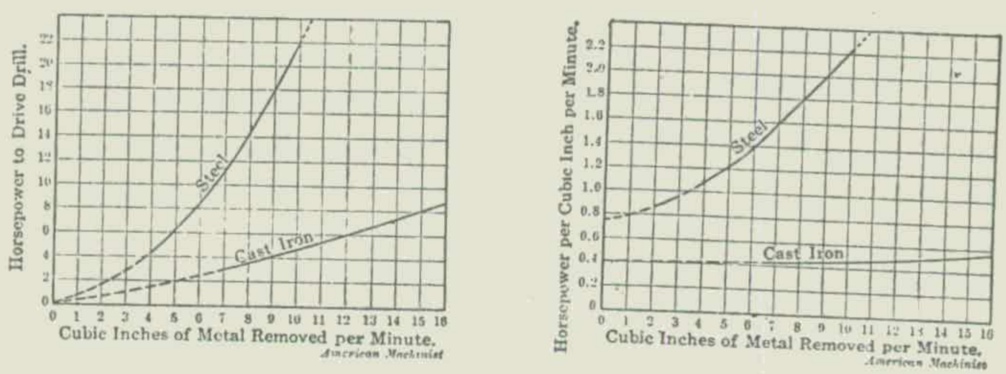


FIG. 1. Relationship of power to metal removal rate

1. WELLER, E. J., BONESTEEL, E. J., and LUCHT, F. W.

2. CARBIDE DRILLS INCREASE TOOL LIFE ON CAST IRON

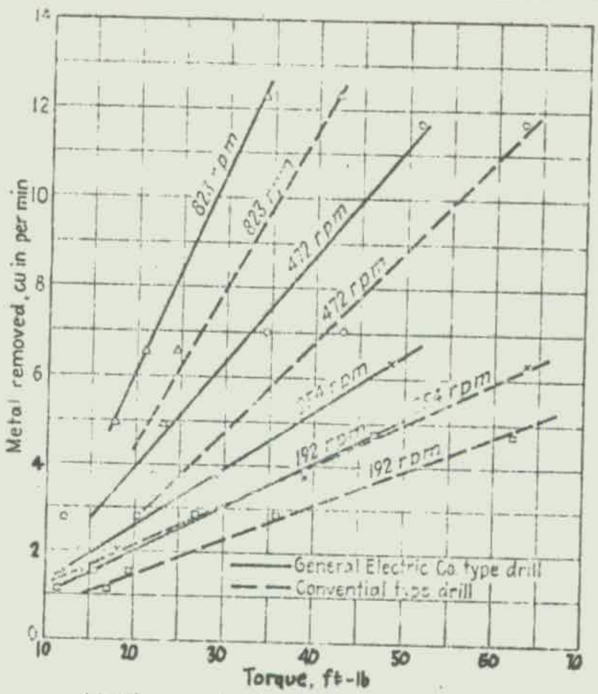
3. THE IRON AGE, May 31, 1915, pp. 75-79

4. The relative vibration of a radial drill press caused by three different designs of carbide tipped drills was determined, Table 1, and compared to conventional drills. Although the carbide tipped drills required more torque than conventional drills, Fig. 1, they required less torque and thrust to remove a unit volume of material. A comparison of the horsepower per unit volume of material removed for the carbide drills and conventional drills is given in Table 2.

RELATIVE CUTTING VIBRATION

Speed		Feed	Thrust				Horsepower Per Cu. In. Per Min.				Relative Vibration		
RPM	FPM	In/Rev.	G-E Type	Union Special Type	Conventional Type	Union Heavy Service Type	G-E Type	Union Special Type	Conventional Type	Union Heavy Service Type	G-E Type	Union Special Type	Conventional Type
192	56.5	0.006	375	425	675	600	0.37	0.38	0.54	0.46	2	3	3.5
		0.008	425	475	775	700	0.37	0.34	0.46	0.42	4	5	3.5
		0.015	650	800	1210	1175	0.34	0.37	0.46	0.48	8	10	5
		0.025	925	1250	1900	1800	0.38	0.42	0.48	0.51	14	11	4
254	75	0.006	375	450	600	550	0.38	0.38	0.45	0.43	2	2.5	3
		0.008	425	475	700	675	0.33	0.40	0.43	0.42	3	5.5	3
		0.015	625	850	1150	1200	0.37	0.44	0.50	0.45	7	6	3.5
		0.025	875	1300	1850	1825	0.37	0.44	0.49	0.52	10	6.5	4
472	139	0.006	350	Unable	425	575	0.48	0.54	0.65	0.61	0.75	0.75	0.75
		0.008	425	to	680	675	0.42	0.43	0.60	0.60	1	1	0.75
		0.0'5	740	Read	1150	1050	0.44	0.42	0.55	0.54	2	2	1.5
		0.025	925	1100	1750	1650	0.39	0.40	0.49	0.49	3.5	4	1
823	242	0.006	375	350	550	550	0.55	0.57	0.66	0.63	0.5	0.75	0.75
		0.008	425	450	625	600	0.49	0.51	0.59	0.58	0.75	1	0.5
		0.015	600	625	1175	950	0.43	0.45	0.54	0.50	1	2	0.5

TABLE 1



—Metal removal rates for conventional v. G-E drill at different speeds.

FIG. 1

DRILL PERFORMANCE

Type of drill	Range of hp/in³/min
G-E type	0.53 to 0.55
Union Special	0.34 to 0.57
Conventional heavy service	0.42 to 0.63
Conventional	0.43 to 0.68

TABLE 2

1. BENEDICT, B. W. and LUKENS, W. D.

2. AN INVESTIGATION OF TWIST DRILLS

3. ENGINEERING EXPERIMENT STATION, UNIVERSITY OF ILLINOIS, BULLETIN NO. 103, 1917, Vol. 15, No. 13, pp. 144

4. Tests were conducted to determine the effect of varying the geometry of the drill on the torque and thrust of drilling.

   The factors that were varied were helix angle, point angle, clearance angle, edge angle, cutting angle, chisel edge, and the cutting speed and feed rate of the drill. The results obtained are:

   1) As the helix angle increases to about 35 degrees the power required for drilling decreases. The power increases for helix angles greater than 40 degrees. This is shown in Figs. 1 and 2.

   2) As the point angle is varied between 108 to 138 degrees the torque is not greatly effected. For point angles greater than 118 degrees the thrust increases rapidly, Figs. 3 and 4.

   3) Variations in the clearance angle have little effect on torque and thrust.

   4) In drilling soft cast iron the values of torque and thrust increase directly with feed. An increase in speed causes a reduction in the torque and thrust as shown in Fig. 5.

   5) Drilling a pilot hole the diameter of which equals the chisel edge width of a larger drill will reduce the thrust on the larger drill by 60-70 percent.

   6) When drilling holes over 3 inches deep use a drill with a large helix and a high speed.

   7) Rounding the corners of the drill on the drill periphery may increase tool life 3 to 10 times.

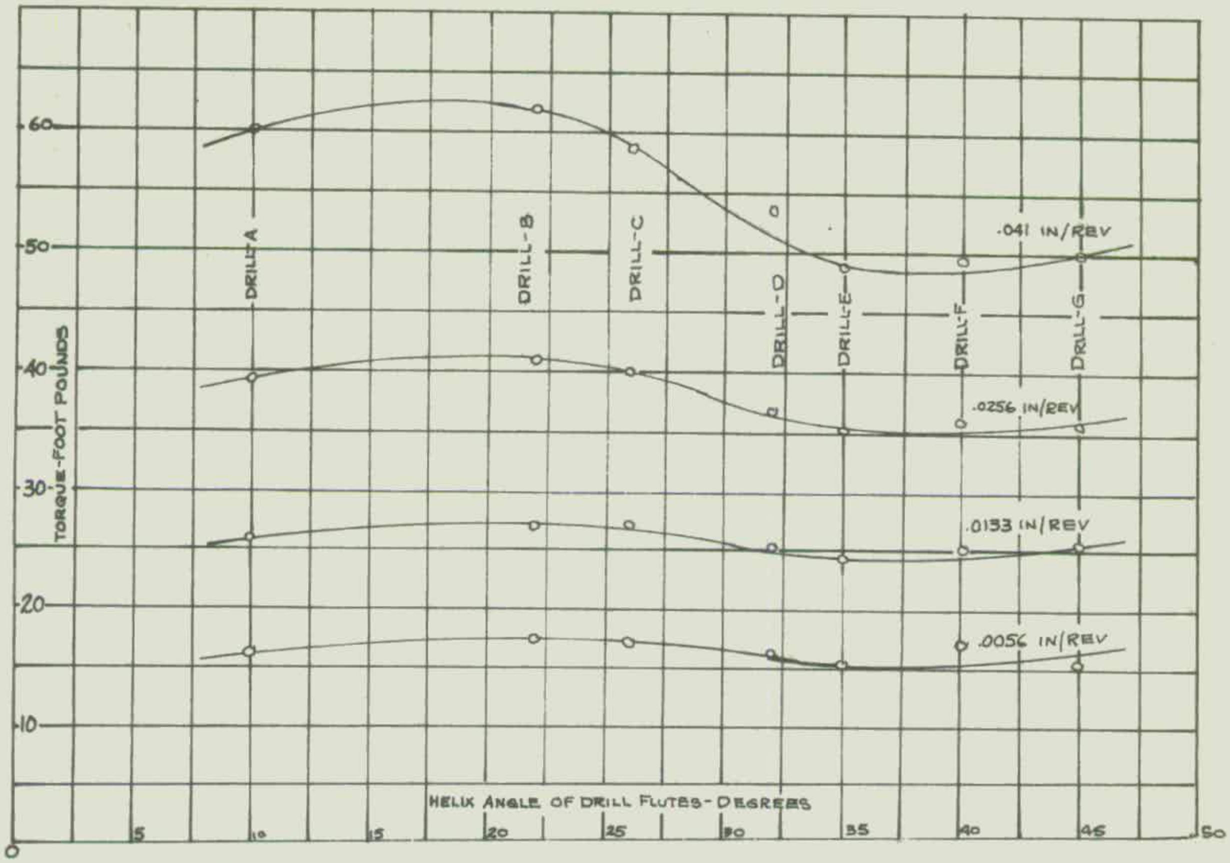


FIG. 1. Effect of helix angle on torque for various feed rates

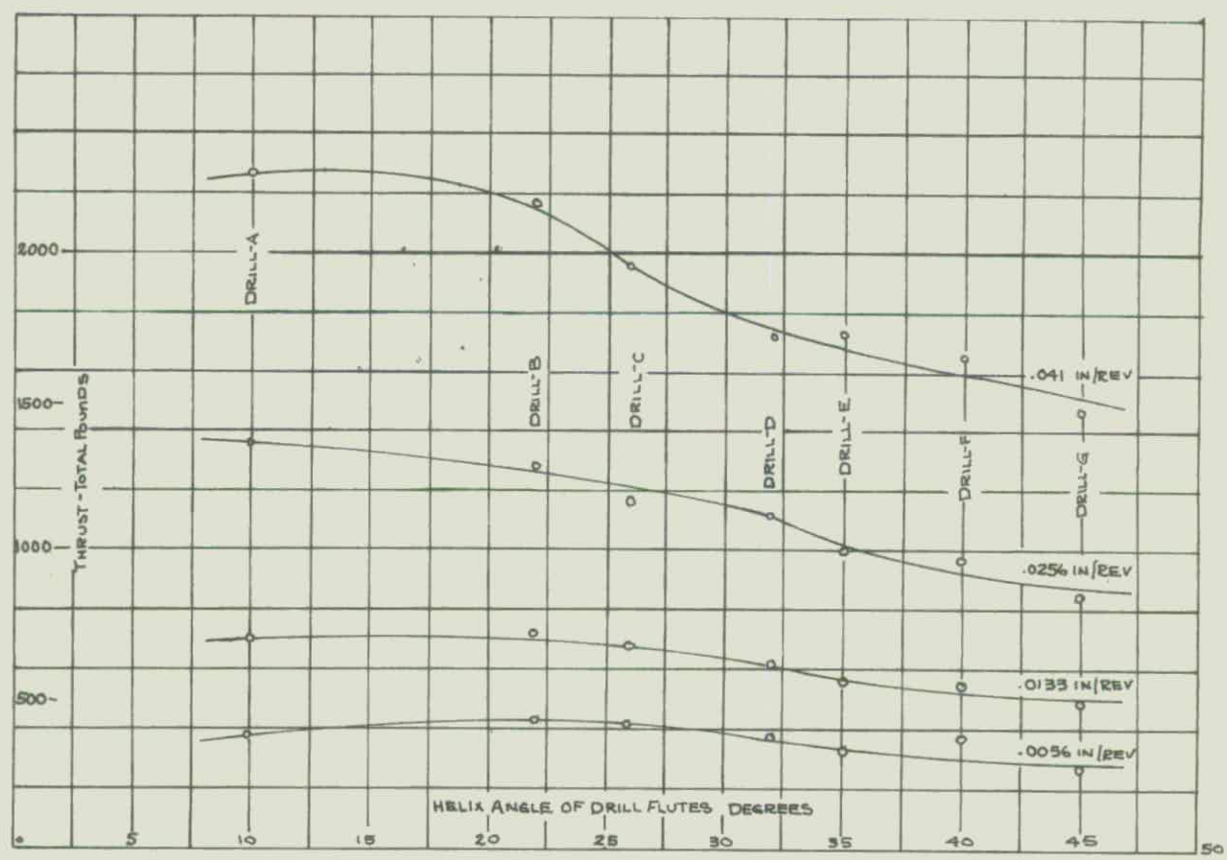


FIG. 2. Effect of helix angle on thrust for various feed rates

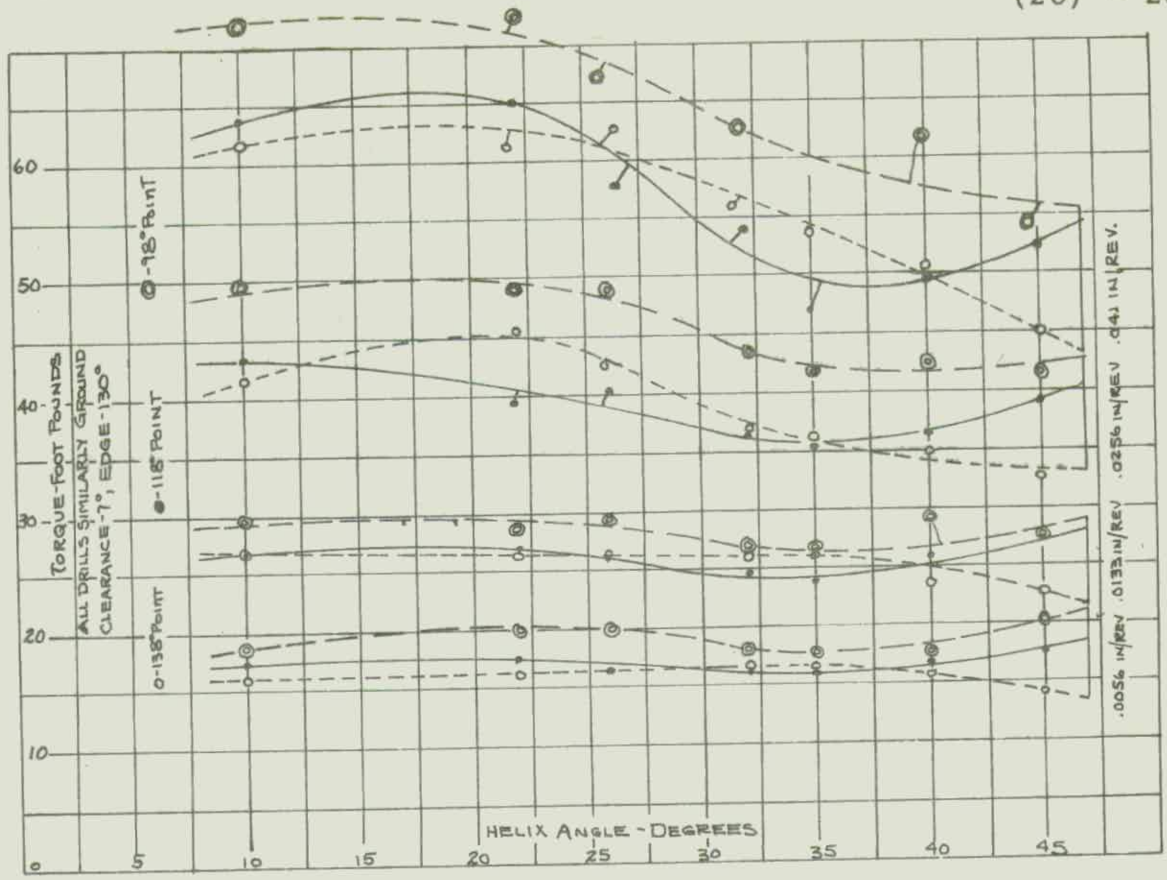


FIG. 3. Effect of point angle on torque for different feed rates

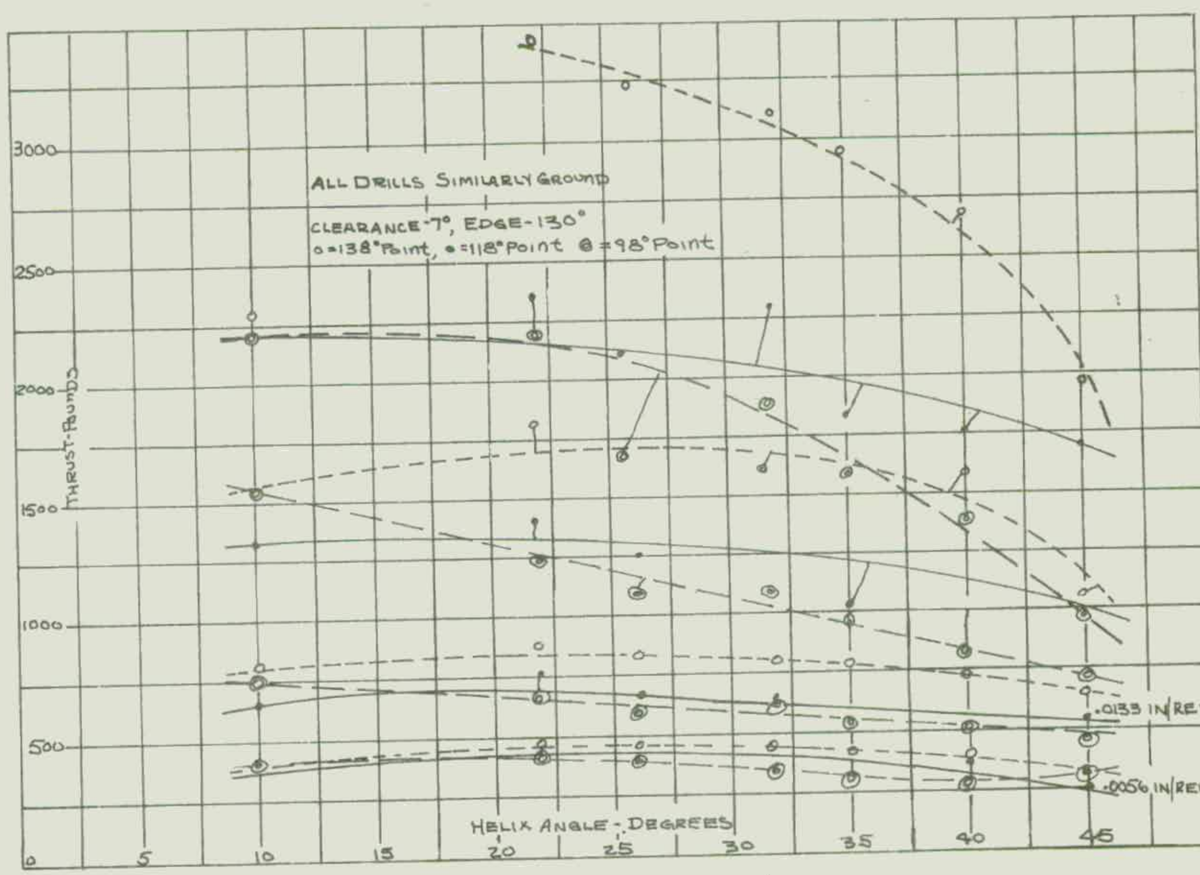


FIG. 4. Effect of point angle on thrust for different feed rates

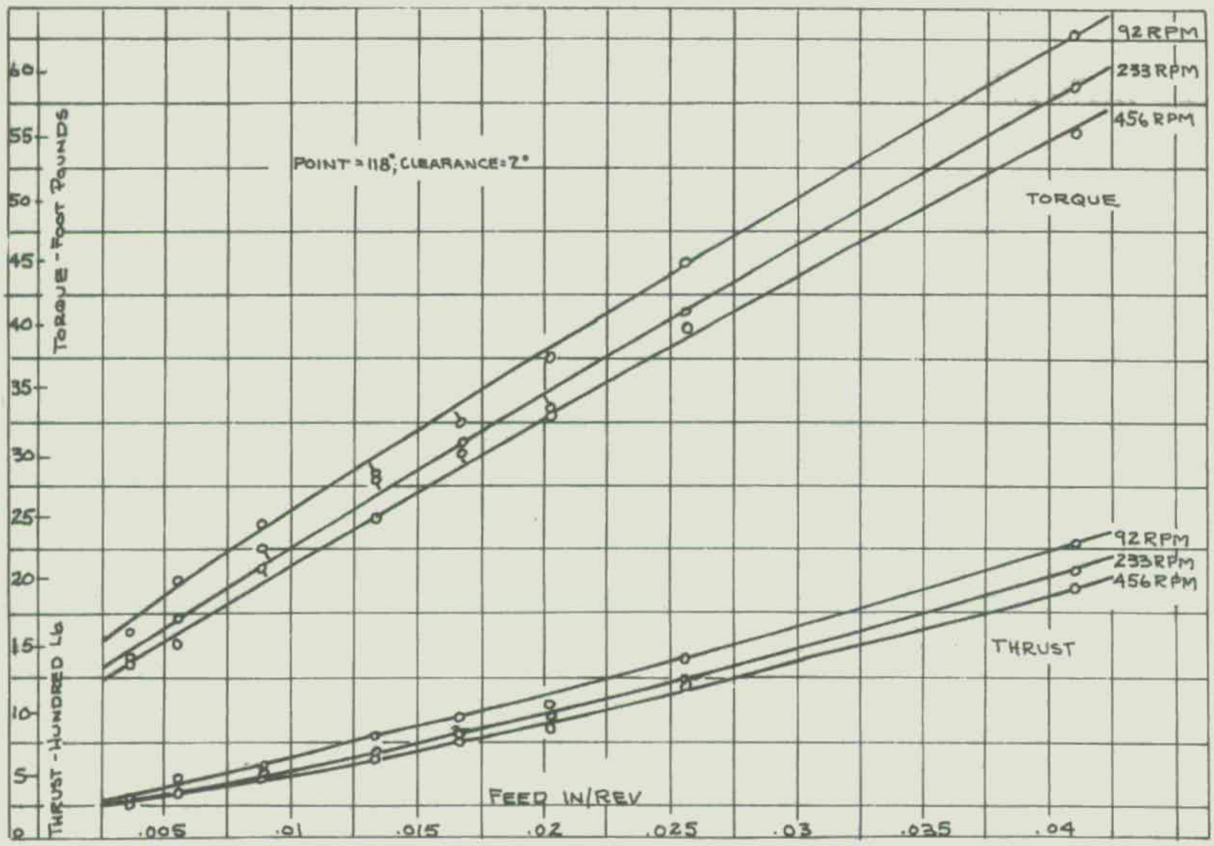


FIG. 5. Relationship between torque, thrust and feed rate for different drill speeds

1. HAMMOND, E. K.

2. SPEEDS AND FEEDS FOR DRILLING

3. MACHINERY, 1918, April, pp. 715-720

4. The proper speed for drilling is the speed at which a balance is obtained between a lower production rate due to lower speeds and lost production time for drill sharpening due to higher speeds.

   When drilling machine steel a speed of 30 fpm should be used, for cast iron 35 fpm, and for brass a speed of 60 fpm. For drills up to 1/2 in. diameter the feed rate should be 0.004 to 0.007 ipr while for larger sizes feed rates of 0.005 to 0.015 ipr can be used. When using high speed steel drills, the speeds can be increased 100 to 125%. A list of possible speeds and feeds for various metals is given in Table 1.

   It is recommended that these values be tried for each material. If the corners of the drill tend to wear after use, the speed should be reduced while if the cutting edges chip or break, the feed rate should be reduced.

   The effect of the clearance or relief angles and the web thickness on the feed force (thrust) was noted. Although no data was given a clearance angle of less than 12 degrees was reported to increase the thrust force over that of a standard drill while an increase in the clearance angle did not reduce the thrust lower than a conventional drill. Reducing the web thickness 10% reduced the thrust while increasing the web thickness increased the thrust.

TABLE 1. CUTTING SPEEDS

Diam., Inches	FEET PER MINUTE 15	20	25	30	35	40	45	50	55	60	65	70	75	80	85
	Revolutions per Minute														
1/16	917.	1223.	1528.	1834.	2140.	2445.	2751.	3057.	3363	3668	3974	4280	4586	4891	5197
1/8	459.	611.	764.	917.	1070.	1222.	1375.	1528.	1681	1834	1986	2139	2292	2445	2598
3/16	306.	408.	509.	611.	713.	815.	917.	1019.	1121	1222	1325	1426	1529	1630	1732
1/4	229.	306.	382.	458.	535.	611.	688.	764.	851	917	994	1070	1147	1222	1300
5/16	183.	245.	306.	367.	428.	489.	550.	611.	672	733	794	856	917	978	1039
3/8	153.	204.	255.	306.	357.	408.	458.	509.	560	611	662	713	764	815	865
7/16	131.	175.	218.	262.	306.	349.	393.	437.	481	524	568	611	656	699	743
1/2	115.	153.	191.	229.	268.	306.	344.	382.	420	459	497	535	573	611	649
9/16	102.	136.	170.	204.	238.	272.	306.	340.	373	407	441	475	509	543	577
5/8	91.8	123.	153.	184.	214.	245.	276.	306.	337	367	398	428	459	489	520
11/16	83.3	111.	138.	167.	194.	222.	249.	273.	300	333	360	389	416	444	472
3/4	76.3	102.	127.	153.	178.	203.	229.	254.	279	306	330	357	381	408	432
13/16	71.1	94.8	119.	142.	166.	190.	213.	237.	261	284	308	332	356	379	403
7/8	65.5	87.3	109.	131.	153.	175.	196.	219.	241	262	285	306	329	349	372
15/16	61.0	81.4	101.	122.	142.	163.	183.	204.	224	244	265	285	305	326	346
1	57.3	76.4	95.5	115.	134.	153.	172.	191.	210	229	258	267	287	306	325
1 1/16	53.9	71.8	89.8	108.	126.	144.	162.	180.	197	215	233	251	269	287	305
1 1/8	51.0	68.0	85.0	102.	119.	136.	153.	170.	187	204	221	238	255	272	289
1 3/16	48.3	64.4	80.5	96.6	113.	129.	145.	161.	177	193	209	225	242	258	274
1 1/4	45.8	61.2	76.3	91.8	107.	123.	137.	153.	168	183	199	214	230	245	260
1 5/16	43.6	58.2	72.8	87.3	102.	116.	131.	146.	160	175	189	204	218	233	247
1 3/8	41.7	55.6	69.5	83.3	97.2	111.	125.	139.	153	167	180	195	208	222	236
1 7/16	39.8	53.0	66.3	79.5	92.8	106.	119.	133.	146	159	172	186	199	212	225
1 1/2	38.2	50.8	63.7	76.3	89.2	102.	115.	127.	140	153	165	178	191	204	216
1 9/16	36.6	48.8	61.0	73.2	85.4	97.6	110.	122.	134	146	159	171	183	195	207
1 5/8	35.0	47.0	58.8	70.5	82.2	93.9	106.	117.	129	141	152	165	176	188	199
1 11/16	33.9	45.2	56.5	67.8	79.1	90.4	102.	113.	124	136	147	158	170	181	192
1 3/4	32.7	43.6	54.5	65.5	76.4	87.3	98.2	109.	120	131	142	153	164	175	185
1 13/16	31.7	42.2	52.8	63.3	73.9	84.4	95.0	106.	116	127	137	148	158	169	179
1 7/8	30.6	40.7	50.9	61.1	71.3	81.5	91.9	102.	112	122	133	143	153	163	173
1 15/16	29.6	39.4	49.3	59.1	69.0	78.8	88.7	98.5	108	118	128	138	148	158	167
2	28.7	38.2	47.8	57.3	66.9	76.4	86.0	95.5	105	115	124	134	143	153	162

Diam., Inches	FEET PER MINUTE 90	95	100	110	120	125	130	140	150	160	170	175	180	190	200
	Revolutions per Minute														
1/16	5502	5808	6114	6725	7337	7643	7948	8560	9171	9782	....	....	....	....	....
1/8	2750	2903	3056	3362	3667	3820	3973	4278	4584	4890	5195	5348	5501	5806	6112
3/16	1834	1936	2038	2242	2446	2548	2649	2853	2157	3261	3465	5367	3668	3872	4076
1/4	1376	1453	1528	1681	1734	1910	1986	2139	2292	2445	2598	2674	2750	2903	3056
5/16	1100	1161	1222	1344	1466	1527	1589	1711	1833	1955	2077	2139	2200	2322	2444
3/8	916	967	1018	1121	1222	1273	1323	1425	1527	1629	1731	1782	1832	1934	2036
7/16	786	830	874	961	1049	1093	1136	1224	1311	1398	1486	1530	1573	1661	1748
1/2	688	726	764	840	917	955	993	1070	1146	1222	1299	1337	1375	1452	1528
9/16	611	645	679	747	813	869	883	951	1019	1086	1154	1188	1222	1290	1358
5/8	552	581	612	673	736	765	796	857	918	979	1040	1071	1102	1163	1224
11/16	500	527	555	611	666	692	722	770	833	888	944	971	999	1054	1110
3/4	458	483	508	559	610	635	661	711	762	813	864	889	914	965	1016
13/16	427	450	474	521	569	593	616	664	711	758	806	830	853	901	948
7/8	392	416	438	482	526	548	569	613	657	701	745	767	788	832	876
15/16	366	387	407	448	488	509	529	570	611	651	692	712	733	773	814
1	344	363	382	420	458	478	497	535	573	611	649	669	688	726	764
1 1/16	323	341	359	395	431	449	467	503	539	579	610	628	646	682	718
1 1/8	306	324	340	374	408	425	442	476	510	544	578	595	612	646	680
1 3/16	290	306	322	354	386	403	419	451	483	515	547	564	580	612	644
1 1/4	274	291	306	337	367	383	398	428	459	490	520	536	551	581	612
1 5/16	262	276	291	320	349	351	378	407	437	466	495	509	524	553	582
1 3/8	250	264	278	306	334	348	361	389	417	445	472	487	500	528	556
1 7/16	239	272	265	292	318	331	345	371	398	424	451	464	477	504	530
1 1/2	230	241	254	279	305	318	330	356	381	406	432	445	457	483	508
1 9/16	220	232	244	268	293	305	317	342	366	390	415	427	439	464	488
1 5/8	212	222	234	257	281	293	304	328	351	374	398	410	421	445	468
1 11/16	203	215	226	249	271	283	294	316	339	362	384	396	407	429	452
1 3/4	196	207	218	240	262	273	283	305	327	349	371	382	392	414	436
1 13/16	190	200	211	232	253	264	274	295	317	338	359	369	380	401	422
1 7/8	184	194	204	224	244	255	265	286	306	326	347	357	367	388	408
1 15/16	177	187	197	217	236	246	256	276	296	315	335	345	355	374	394
2	172	181	191	210	229	239	248	267	287	306	325	334	314	363	382

Machinery

1. BENEDICT, B. W.

2. HELIX ANGLE OF TWIST DRILLS

3. AMERICAN MACHINIST, 1920, Vol. 53, No. 26, pp. 1175-1178

4. Experimental evidence indicates that a drill with a helix angle of 35° requires less torque to drill cast iron than drills with helix angles of 22°, 26°, 32°, 40° and 45°. The thrust decreased with increasing helix angle and was the lowest for a drill with a helix angle of 45° although "a number of mechanical factors make it inadvisable to consider the use of helix angles above 35°".

   The author states that a clearance angle of 6° and not the commonly used 12° angle is the best one to use with a helix angle of 35°. This provides a large enough quantity of metal for the transmission of heat from the cutting edge and combined with the fact that the author feels that the 35° helix angle drill generates less heat than other drills, this gives a drill of greater endurance.

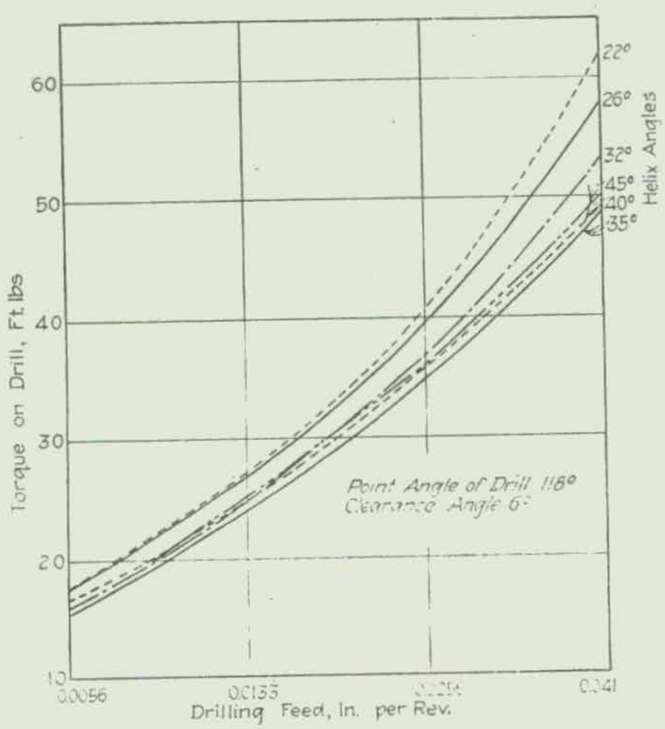


FIG. 1. Torque vs. feed in various helix angles

1. SCHWARTZ, A. A. and FLAGLE, W. W.

2. THE SIGNIFICANCE OF TOOL TEMPERATURE AS A FUNCTION OF THE CUTTING RESISTANCE OF METALS

3. PROCEEDINGS ASTM , 1923, Vol. 23, Part II, pp. 27-39

4. Utilizing standard iron-constantan thermocouples inserted into the oil holes of 3/4" diam. drills, the authors established drill temperature versus penetration distance. In their experiment the drill was held stationary while the workpiece rotated and the workpiece was notched so that the remaining metal was removed when the cutting edges of the drill passed the notched area, Fig. 1.

   It was suggested that this would be an inexpensive method of indicating the machinability of metals.

   A typical drill temperature penetration curve is shown in Fig. 2.

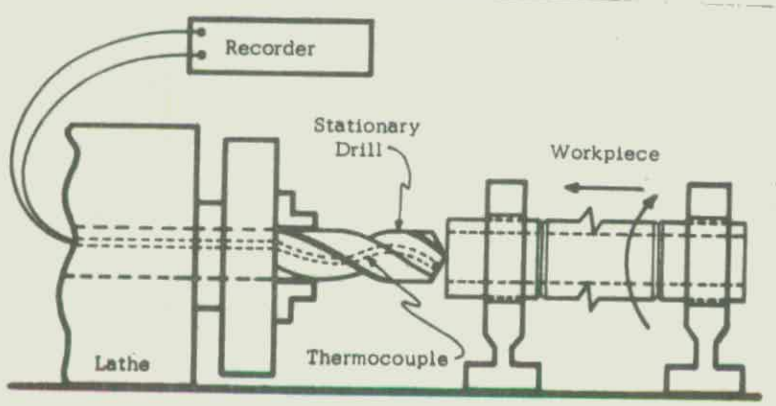


FIG. 1. Experimental procedure

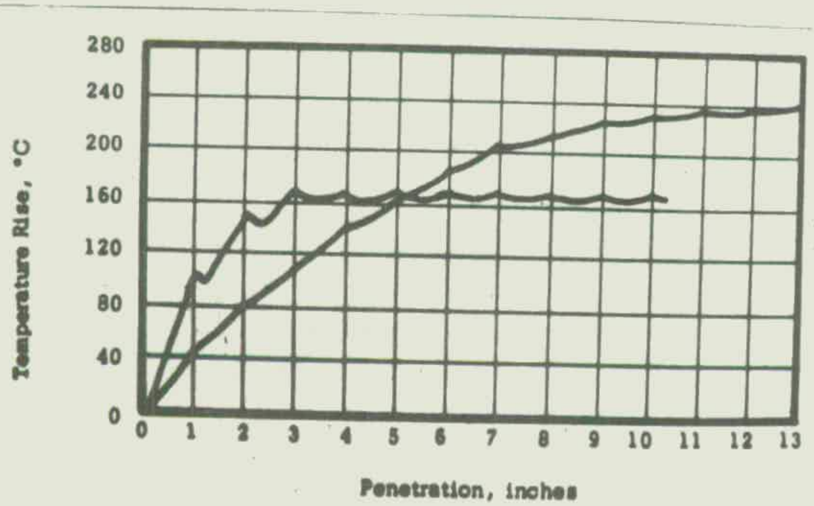


FIG. 2. Drill temperature vs. penetration

1. BENEDICT, BRUCE W. and HERSHEY, A. E.

2. AN INVESTIGATION OF TWIST DRILLS (PART 2)

3. ENGINEERING EXPERIMENT STATION, UNIVERSITY OF ILLINOIS, Bulletin No. 159, 1926, Vol. 24, No. 11, p. 76

4. The authors made a study of the relation of helix angle to power consumption and endurance in drilling gray cast iron and steel. It was found that:

   1. The torque and thrust required for drilling decreased as the helix angle increased from 15 to 45 degrees. This is shown in Figs. 1 and 2.

   2. Drill endurance was not greatly affected by varying the helix angle between 26 and 35 degrees when drilling cast iron and steel.

   3. Considering endurance and power consumption, drills with a helix angle between 32 and 35 degrees give satisfactory performance.

   4. Drill torque may be used to determine the machinability of metals.

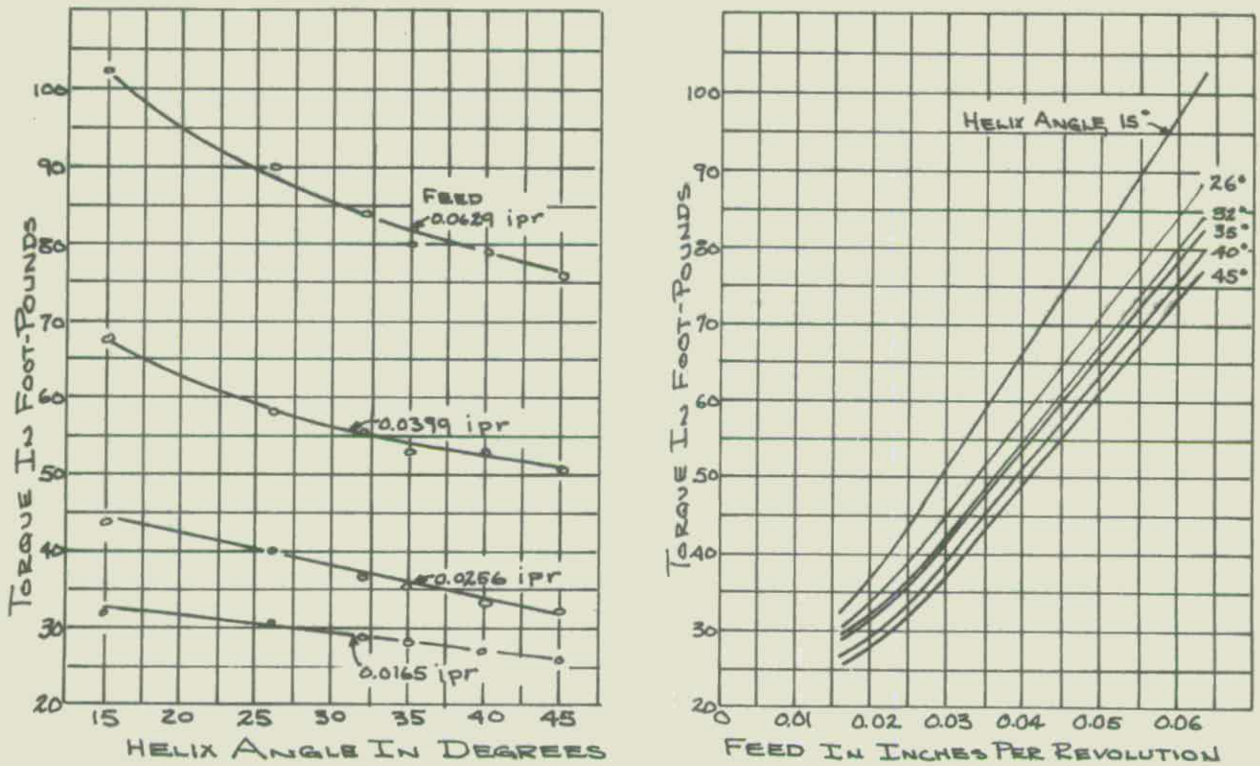


FIG. 1. Influence of helix angle and feed rate on torque when drilling gray cast iron

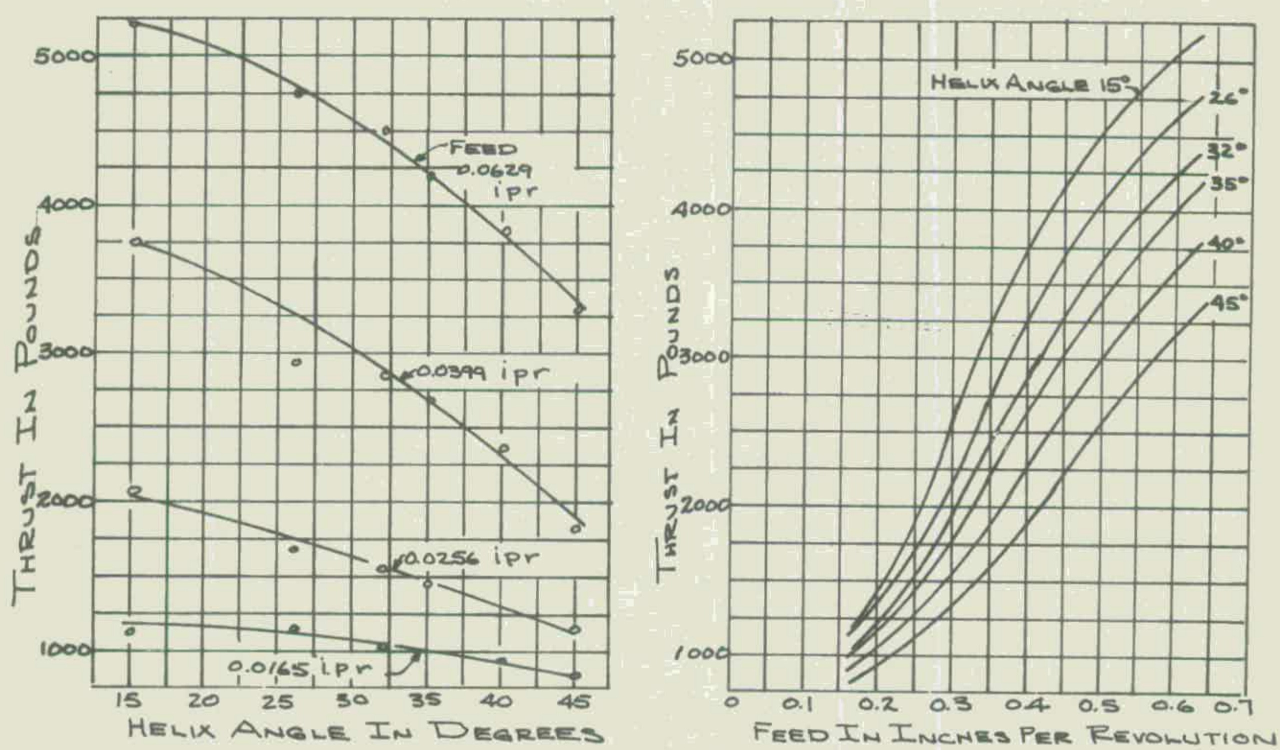


FIG. 2. Influence of helix angle and feed rate on thrust when drilling cast iron

1. ANONYMOUS

2. TESTING DRILLS AND DRILL STOCK AT THE MORSE FACTORY

3. AMERICAN MACHINIST, 1927, Vol. 67, No. 24, pp. 941-943

4. A description of the testing that drills and drill material undergo at the Morse Twist Drill & Tool Co. The testing includes the use of a machine to test torque and point pressure when drilling. A chart (Fig. 1) is shown of the torque obtained when drilling four different metals.

   There is also a torsion testing machine to test the behavior of the drills and bar stock under stress.

   An endurance test consisted of using the drills under normal operating conditions while drilling a given number of holes and it is then exchanged with another drill. This continues until the drill no longer cuts. It is then sharpened and the test continued, with the drill performance carefully recorded.

   Drill hardness was checked using a Rockwell hardness tester and "the old fashioned and reliable file test". The inspector is provided with carefully hardened plugs as a comparison piece.

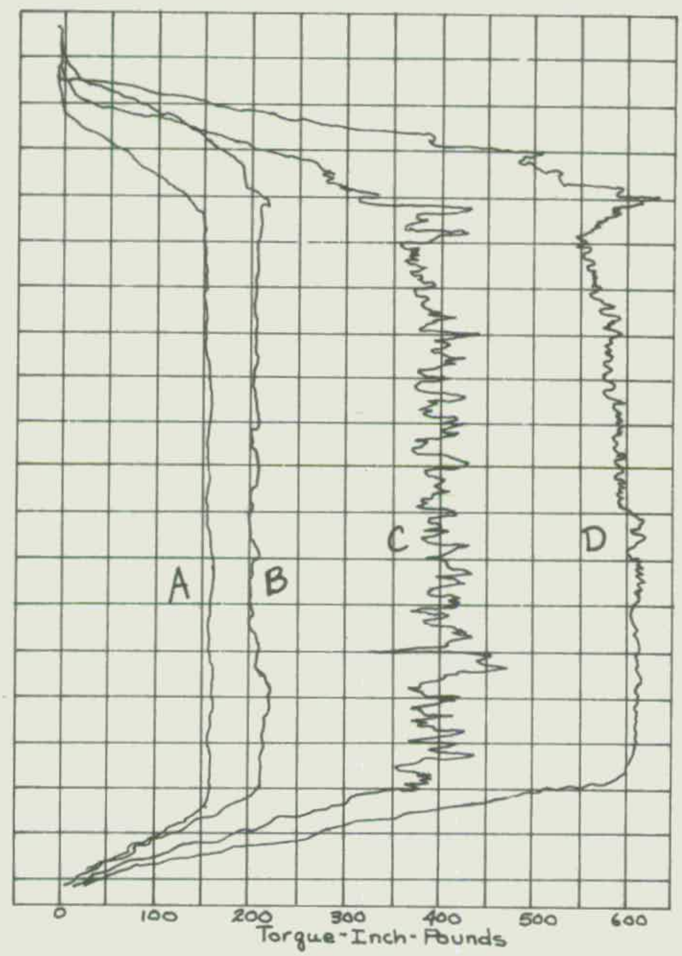


FIG. 1. Torque obtained when drilling four metals. A-Soft Brass, B-Cast Iron, C-Machine steel, D-High Carbon Chrome-Vanadium steel

1. PANZER, VON R.

2. EIN VERSUCH ZUR KLÄRUNG DER VORSCHUBFRAGE IM SENKRECHTBOHR-MASCHINENBAU (Feed of Vertical Drilling Machine)

3. WERKSTATTSTECHNIK, 1928, Vol. 22, No. 9, pp. 261-267

4. Mathematically the required horsepower (N) of a drilling machine is known as

$$N = \frac{P.v}{75} \quad (1)$$

where P is the force and v is the cutting speed. A modified equation from (1) can be presented as

$$N=2\,\frac{W.v}{75\cdot 60\cdot 2} = \frac{W.v}{4500} = \frac{D\cdot\vartheta\cdot K\cdot v}{2\cdot 2\cdot 4500} = \frac{D\cdot\vartheta\cdot K\cdot v}{18000} \quad (2)$$

where W = P, D = drill diameter

Feed rate $\vartheta = \frac{N}{0.22D}$ mm/rev for steel

$\vartheta = \frac{N}{0.11D}$ mm/rev for cast iron

and K is a number established by the kind of material (K = 100 for cast iron, and K = 200 for steel).

In the case of drilling in a predrilled hole (countersinking)

Resistance $Ws = f\cdot K$

where f = cross section of cut

$$f = \frac{D-d}{2} \cdot \frac{\vartheta}{a} \quad (3)$$

a = Number of lip edges

Therefore, $W = \frac{D-d}{2} \cdot \frac{\vartheta}{a} \cdot K$

The required horsepower for countersinking therefore, should be

$$Ns = \frac{a\cdot W\cdot v}{60.75} \quad (4)$$

where $v' : v = \left(\frac{D+d}{2}\right)\pi n : D\pi n$

and $v' = \frac{v}{2}\left(1+\frac{d}{D}\right) \quad (5)$

Then, $$Ns = a\,\frac{D-a}{2} \cdot \frac{\vartheta}{2} \cdot K \cdot \frac{v}{2}\left(1 + \frac{d}{D}\right) \cdot \frac{1}{60 \cdot 75}$$

$$= \frac{\vartheta \cdot K \cdot v}{2 \cdot 60 \cdot 75}\left(\frac{D-d}{2}\right)\left(1 + \frac{d}{D}\right)$$

$$= \frac{\cdot K \cdot v}{1800 \cdot D}\,(D^2 - d^2) \qquad (6)$$

1. BOSTON, O. W. and OXFORD, C. J.

2. POWER REQUIRED TO DRILL CAST IRON AND STEEL

3. TRANS. ASME, MSP-52-2, 1930, Vol. 52, pp. 5-26

4. Drilling tests were run with drills from ½ in. to 1½ in. diameter on 17 different steels and 2 different cast irons.

   It was found that torque and thrust were not greatly affected by changes in cutting speed with feed rate, material and lubrication constant. General equations for determining torque and thrust when drilling cast iron and steel were determined as:

   1) For cast iron:

      Torque $T = C_1 f^{0.6} d^2$

      Thrust $Th = C_3 f^{0.6} d$

   2) For steel:

      Torque $T = C_2 f^{0.78} d^{1.8}$

      Thrust $Th = C_4 f^{0.6} d$

   where f is the feed rate in inches per revolution, d is the drill diameter in inches and C is a constant depending upon the material being cut.

   The torque in drilling steel is related to the type of steel, the carbon content and the microstructure of the steel.

1. SCHLESINGER, G. and KURREIN, M.

2. DAS BOHREN VON GUSSEISEN IN DER FEINMECHANIK (Drilling of Cast Iron in Precision Manufacture of Apparatus)

3. WERKSTATTSTECHNIK, 1930, Vol. 24, No. 4, pp. 89-94

4. Eight kinds of high speed drills of 5 mm diameter are submitted to systematic comparative drilling tests. The drills were reground by a newly developed drill grinding machine which allowed sufficient symmetry of the drill to be obtained.

   Considering that drilling of a precision machined part would be operated on a mass-production basis, the drills for this investigation were not selected but simply used in the condition in which they were received.

   The drilling speed was chosen as 50 m/min (RPM = 2900). A sensitive feeding device was employed in which feed was achieved by use of a constant weight mechanism.

   The research result can be given as follows:

   1) The drill life varied greatly.

   2) Different types of drill wear were observed:

      a) Linear wear occurred on the chisel and lip edge
      b) As the corner of the lip and chisel edge were drilled, a dark brown color was observed
      c) As the chisel edge was rubbed, the corner was rounded and the point of the drill was slightly burned
      d) As the chisel edge was destroyed and burned, the chip became welded together.

1. SCHLESINGER, G.

2. BOHRARBEIT UND BOHRMASCHINE (Drilling and Drilling Machines)

3. WERKSTATTSTECHNIK, 1930, Vol. 24, No. 21, pp. 573-577

4. Construction of drilling machines and practical use of drilling machines depend upon:

   1) Mathematical and mechanical relationships

   2) Thorough investigations from which the drilling with twist drills can be obtained.

   Diameter of drills, drilling speed RPM, torque and required horsepower are factors closely related to both the drill and workpiece materials.

   At constant feed rate(s) the relationship between drill diameter (d) and torque (M), for all kinds of material, can be expressed as

$$M = f(d)$$

   Cutting speed (V) can be related to feed rate as

$$V = f(s)$$

   Practically applicable feed rates can be obtained as

$$s = f(d)$$

   From the relationship $V = \frac{\pi \cdot d \cdot n}{1000}$

   it follows that

$$n = \frac{1000}{\pi} V \cdot \frac{1}{d}$$

   Then

$$\lg n = \lg \left(\frac{1000}{\pi} V\right) - \lg d$$

   With a constant drilling speed V, then

$$\frac{1000}{\pi} \cdot V = C = \text{const}$$

   Therefore, $\lg n = \lg C - \lg d$

With this relationship a double logarithmic homograph can be obtained as shown in Fig. 1. Using this graph the relationship between drill diameter, drilling speed, RPM, required horsepower and torque can be established.

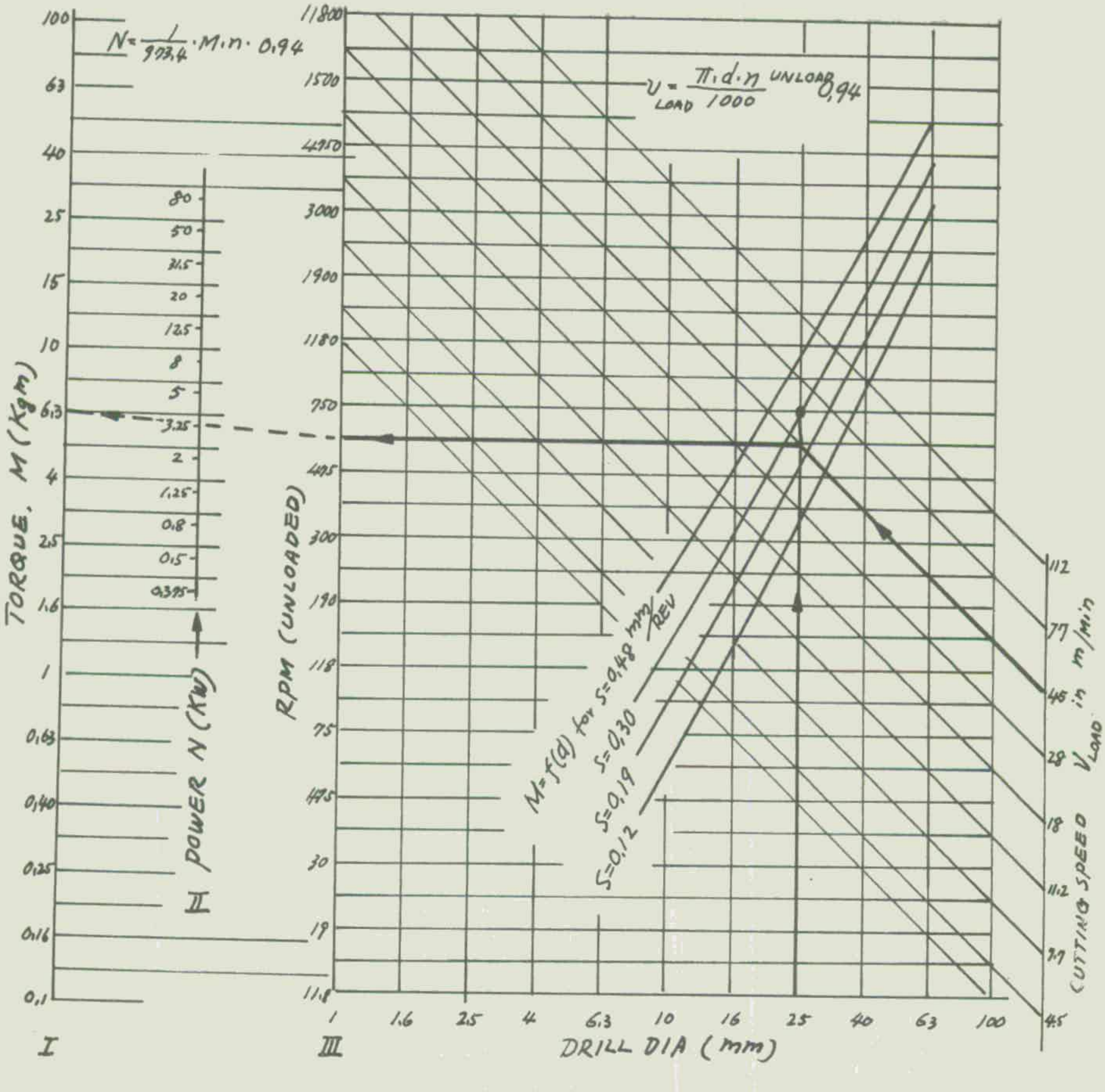


FIG. 1. Homograph for drilling work

1. KRONENBERG, M.

2. ÜBER DEN ZULÄSSIGEN VORSCHUB BEIM BOHREN UND DIE AUSNUTZUNG DER BOHRMASCHINE (Allowable Feed in Drilling and Economic Application of Drilling Machine)

3. WERKSTATTSTECHNIK, 1935, Vol. 28, No. 18, pp. 357-365

4. The resistant moment (W) in drilling can be computed as

$$W = \frac{2 \cdot L \cdot M}{d \cdot G \cdot \varphi} \qquad (1)$$

if the torque (M) and twist angle (φ) are measured for a drill of length L and diameter d where G is the modulus of rigidity. The experimental results given in Fig. 1 indicated that the resistant moment can be estimated by

$$W = 0.02\ d^3 \qquad (2)$$

Designating τ as the shearing stress than

$$\tau = \frac{M}{W} \qquad (3)$$

Torque for drilling steel can generally be estimated as

$$M = 0.24\ C_{ks} \cdot s^{0.803} \cdot d^{1.803} \qquad (4)$$

From (2) and (3)

$$\tau = 12\ C_k \cdot s^{0.803} \cdot d^{-1.2} \qquad (5)$$

and

$$\sigma = 1.89\ C_{ks} \cdot s^{0.803} \cdot d^{-1.2} \qquad (6)$$

therefore,

$$\sigma = 0.157\,\tau$$

Using Mohr's circle

$$\tau_{max} = 1.73\,\tau = \frac{1.73 \cdot M}{0.02\ d^3} = 298\ C_{ks} \cdot s^{0.803} \cdot d^{-1.2} \qquad (7)$$

Considering the applicable testing results, the allowable feed rate can be established as

$$S_B = \frac{3.75 \cdot d^{1.5}}{C_{ks}^{1.245}} \text{ mm/U} \quad (8)$$

The highest allowable feed rate in drilling machine can be given as

$$S_M = \frac{P_{max}^{1.245}}{0.5 \cdot C_{ks}^{1.245} \cdot d} \quad \text{mm/U} \quad (9)$$

where P is the thrust force.

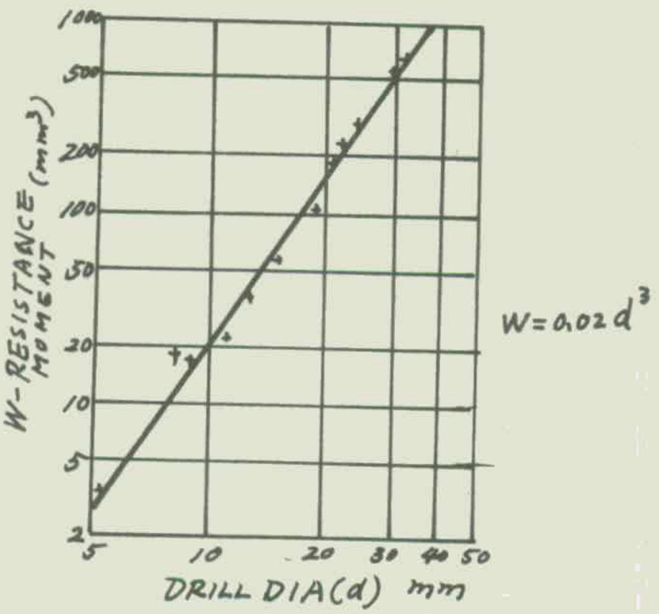


FIG. 1. Relationship between resistance moments and diameters

1. BOSTON, O. W. and GILBERT, W. W.

2. THE TORQUE AND THRUST OF SMALL DRILLS OPERATING IN VARIOUS METALS

3. TRANS. ASME, 1936, Vol. 58, No. 2, pp. 79-89

4. Tests were conducted on small drills 1/8 in. to 1/2 in. in diameter. The influence of helix angle, web thickness, cutting speed and feed on drill torque and thrust is determined along with formulas for finding the torque and thrust when drilling in the metals tested.

   In the first part of the experiment, it was determined that:

   1. The cutting speed had little effect on the torque and thrust (Fig. 1).

   2. The torque and thrust decreased as the helix angle increased from 21 degrees to 40 degrees (Fig. 2).

   3. As the web thickness increased from 0.029 to 0.043 for 5/32 in. drills the torque and thrust both increased with the thrust increasing 41 percent (Fig. 3).

   Nine materials were used in the drill tests and the following formulas were obtained for the torque and thrust:

Material	Torque	Thrust
SAE 1020 Steel	$T=1740\ f^{0.78}\ d^{1.8}$	$B=104{,}000\ f^{0.87}d$
SAE 1035 Steel	$T=1300\ f^{0.78}\ d^{1.8}$	$B=96{,}000\ f^{0.87}d$
0.97% C Tool Steel	$T=1842\ f^{0.78}\ d^{1.8}$	$B=133{,}100\ f^{0.87}d$
SAE 3150 Steel	$T=1500\ f^{0.78}\ d^{1.8}$	$B=108{,}500\ f^{0.87}d$
SAE 1112 Steel	$T=1000\ f^{0.78}\ d^{1.8}$	$B=74{,}100\ f^{0.87}d$
Gray Cast Iron	$T=347\ f^{0.69}\ d^{1.7}$	$B=25{,}800\ f^{0.73}d$
Malleable Cast Iron	$T=689\ f^{0.78}\ d^{1.8}$	$B=24{,}400\ f^{0.75}d$
Leaded Brass Screw Stock	$T=512\ f^{0.83}\ d^{1.9}$	$B=6{,}160\ f^{0.6}\ d$
Cast Aluminum Alloy SAE 33	$T=556\ f^{0.83}\ d^{1.9}$	$B=90{,}400\ f\ d^{1.2}$

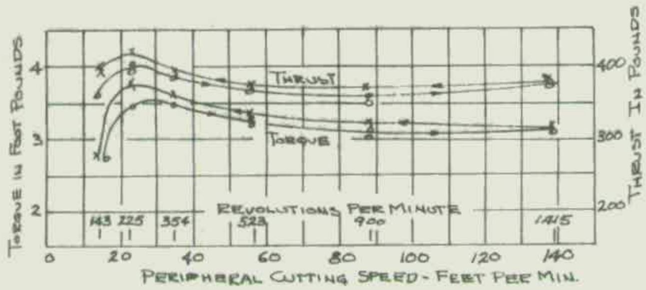


FIG. 1. Effect of drilling speed on torque and thrust

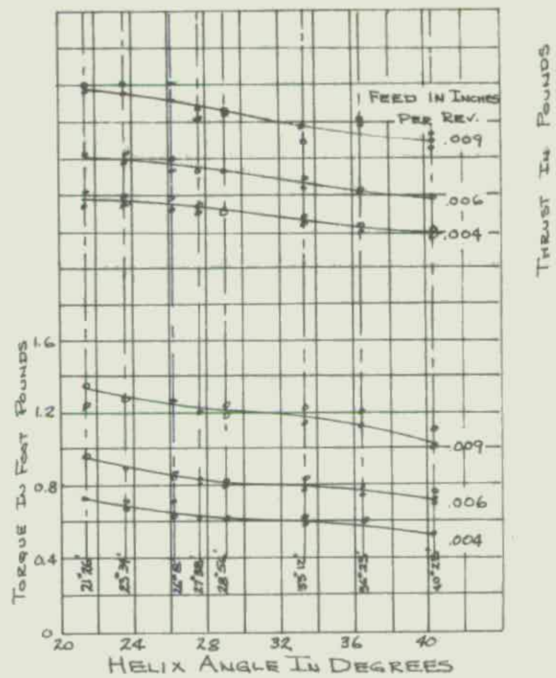


FIG. 2. Effect of helix angle on torque and thrust

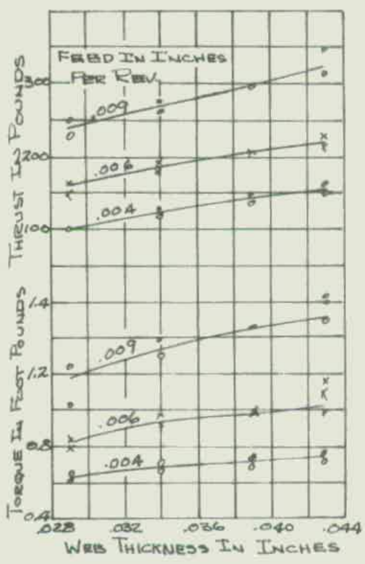


FIG. 3. Influence of web thickness on torque and thrust

1. BOSTON, O. W.

2. DRILLING HIGH MANGANESE STEEL WITH COBALT HIGH SPEED STEEL TWIST DRILLS

3. MACHINERY, 1937, Vol. 43, No. 11, pp. 733-735

4. The author conducted drilling tests in a 13 percent manganese steel with a Brinell hardness of 228.

   The equations for determining the torque and thrust are given as:

   Torque $T = 1355\ f^{0.6}\ d^{1.8}$
   Thrust $F = 32,000\ f^{0.4}\ d^{1.1}$

   The influence of feed rate and drill diameter on torque and thrust is shown in Fig. 1.

   Tests were also run to determine the effect of a cutting fluid. It was found that the torque and thrust values were steadier and the chips were broken up better when a cutting oil was used.

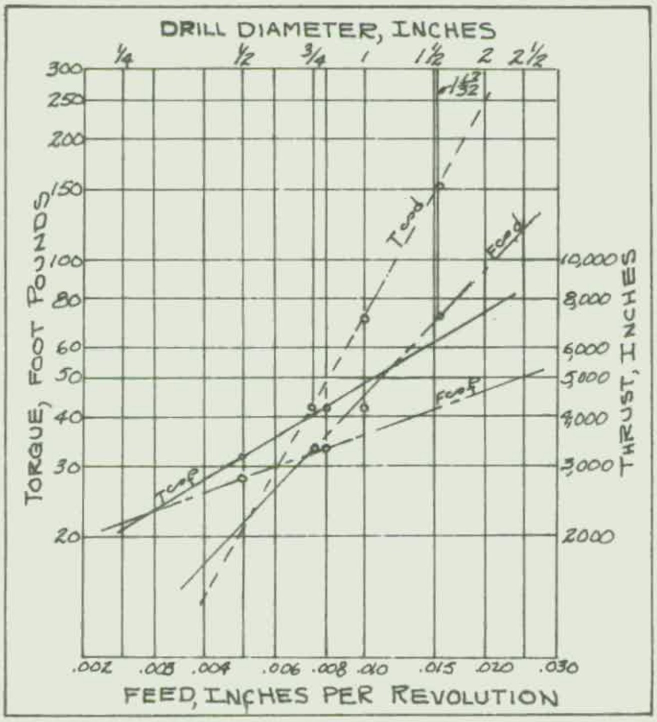


FIG. 1. Effect of varying the feed rate and drill diameter on torque and thrust

1. BOSTON, O. W.

2. CALCULATING MACHINE TOOL POWER REQUIREMENTS

3. MACHINE DESIGN, 1942, Vol. 14, No. 6, pp. 79-83

4. The power required for various metal cutting operations such as turning, milling, planing, drilling, etc. were determined.

   The efficiency of a lathe developing two horsepower at the spindle was found to vary from 45 percent at a speed of 18 RPM to 26 percent at a speed of 750 RPM.

   Equations were developed for predicting the torque and thrust in drilling annealed chrome-vanadium steel, SAE 6150, BHN 187, and a cast iron of BHN 163. The equations are:

   Steel

   $M = 1840\ f^{.78}\ d^{1.8}$

   $T = 53{,}400\ f^{.78}\ d$

   Cast Iron

   $M = 380\ f^{.6}\ d^{2}$

   $T = 14{,}720\ f^{.6}\ d$

   where M = Torque (lb-ft)
   T = Thrust (lb.)
   f = Feed (ipr)
   d = Drill diameter

   The torque, thrust, gross horsepower and net horsepower for drilling these materials is shown in Table I.

   It is shown that for a $1\frac{1}{4}$ in. diameter drill operating in SAE 6150 at a speed of 175 RPM the horsepower due to the thrust force is 0.43 percent of the total horsepower required, the balance being developed by the torque.

TABLE 1

Torque, Thrust and Power in Drilling

Material	Drill Dia. (in.)	Speed rpm	Feed (in./rev)	Torque (lb-ft)	Torque Horse-power (hp)	Thrust (lb)	Thrust Horse-power (hp)	Total Output (hp)	Input Power Gross (kw)	Input Power Tare (kw)	Input Power Net (kw)	Net Input (hp)	Efficiency (%)
SAE 6150 Steel	½	444.5	.009	14.0	1.185	725	.00732	1.193	1.6	.67	0.93	1.24	96
	⅝	368.0	.011	22.3	1.562	838	.00856	1.571	2.025	.67	1.355	1.81	87
	¾	299.7	.012	34.3	1.957	1269	.01153	1.975	2.42	.67	1.75	2.34	84
	1	228.1	.013	62.4	2.71	1862	.01394	2.724	3.176	.57	2.606	3.49	78
	1¼	175.1	.015	110.8	3.694	2430	.01611	3.710	3.87	.57	3.3	4.42	84
	1½	149.0	.015	143.3	4.07	3000	.01693	4.087	4.507	.507	4.0	5.35	76
Cast Iron	½	446.0	.009	6.3	0.535	530	.00614	0.541	1.12	.67	0.45	0.602	90
	⅝	364.4	.011	10.2	0.708	645	.00652	0.715	1.32	.67	0.65	0.870	82
	¾	299.7	.012	15.7	0.896	803	.00728	0.903	1.48	.67	0.81	1.084	83
	1	229.8	.013	27.9	1.221	1088	.00822	1.23	1.72	.50	1.22	1.635	75
	1¼	179.4	.015	46.4	1.585	1403	.00954	1.60	2.025	.45	1.575	2.110	76
	1½	153.4	.015	65.9	1.925	1700	.00988	1.94	2.27	.37	1.90	2.550	76

*Standard twist drills were used with 31-degree helix angle. 121-degree point angle. 136-degree chisel-edge angle and 5-degree relief angle. The ratio of web thickness to diameter was .14 for the ¾-inch and larger drills. .162 for the ½-inch diameter drills, and .185 for drills up to ⅝-inch diameter. Speed 60 feet per minute. Cutting fluid emulsion 1 part soluble oil to 16 parts water.

1. SCHMIDT, A. O., Gilbert, W. W. and Boston, O. W.

2. CORRELATION OF COEFFICIENT OF FRICTION WITH DRILLING TORQUE AND THRUST FOR DIFFERENT TYPES OF CUTTING FLUIDS

3. TRANS. ASME, 1942, Vol. 64, No. 7, pp. 703-709

4. The coefficient of friction of the various cutting fluids was determined with 3 high speed steel pins rubbing on a test piece. The coefficient of friction was calculated with the various values of torque and thrust obtained in these tests.

   The effect of the cutting fluids on the ratio of the coefficient of friction to pressure at seizure is shown in Fig. 1. This shows that mineral oil and water both produce approximately the same coefficient at low pressures while with sulphurized oils the coefficient is reduced.

   Drilling tests were carried out in which the torque and thrust associated with the chisel edge, cutting lips and drill margins could be determined separately. (Fig. 2)

   For the drilling tests the following results were obtained:

   1. All cutting fluids produced a decrease in torque.

   2. The torque due to the cutting lips alone was changed very little by the cutting fluids.

   3. A reduction in torque occurred mainly at the chisel edge and drill margins.

   The results of the tests on the effects of cutting fluids are:

   1. All of the cutting fluids produced a reduction in thrust.

   2. The cutting fluids had little effect on the thrust produced by the cutting edges.

   3. The chisel edge accounts for about 60 percent of the total thrust. (Fig. 3)

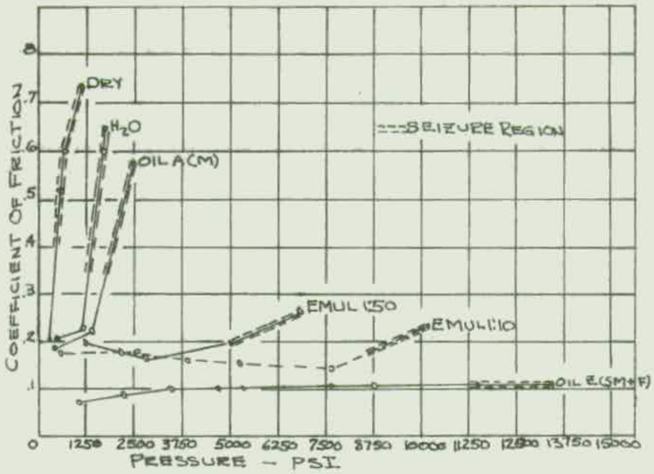


FIG. 1. Effect of cutting fluids on the coefficient of friction

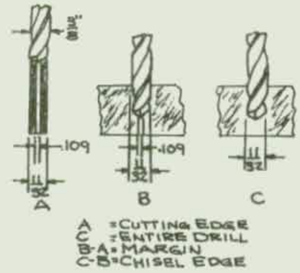


FIG. 2. Drilling Methods

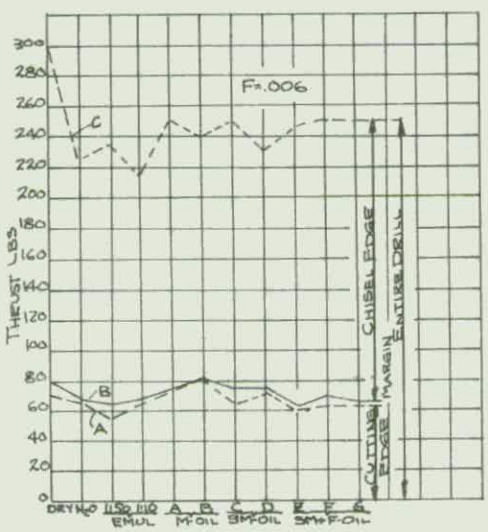


FIG. 3. Effect of cutting fluid on thrust

1. HOAGLAND, F. O.

2. GRIND-DEEP-HOLE DRILLS PROPERLY

3. AMERICAN MACHINIST, 1943, Vol. 87, No. 4, pp. 91-93

4. A procedure is presented for sharpening drills used in drilling gun barrels. The complexity of the grinding varies with different diameter drills. The advantage of machine grinding over hand grinding is stressed in that the properly ground drill produces a quality gun barrel with the quantity desired.

1. MEYER, G. J.

2. PRACTICAL SUGGESTIONS FOR IMPROVEMENT OF TWIST DRILLS

3. AMERICAN MACHINIST, 1944, Vol. 88, No. 19, pp. 106-108

4. Many drills are ruined because of "too thick a center on the point". To correct this, the author experimented with various methods of thinning. In order to further improve the cutting action he had drills made with a radial cut and claims this is the best.

   A new type of holder is explained where the shank end of the drill has a threaded taper that can be inserted into a holder that will accommodate several different size drills.

1. SCHMIDT, A. O., Gilbert, W. W., and Boston, O. W.

2. A THERMAL BALANCE METHOD AND MECHANICAL INVESTIGATION FOR EVALUATING MACHINABILITY

3. TRANS. ASME, 1945, Vol. 67, pp. 225-232

4. Schmidt, et al, used a calorimetric technique, Fig. 1, to determine the energy generated in drilling. The energy generated was found from the increase in temperature of 50 cc of distilled water. This was compared with the energy determined from torque and thrust data and agreed within 1 to 3%.

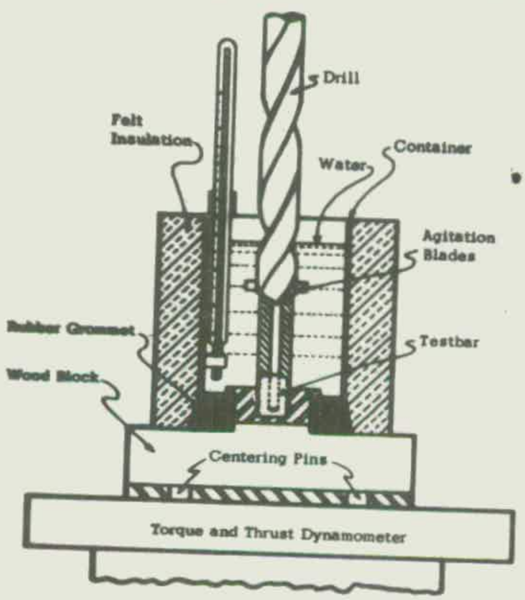


FIG. 1. Calorimetric technique to determine the energy generated in drilling

1. AINSWORTH, W. E. and MUNRO, G.

2. DOES DRILL POINT CLEAR?

3. AMERICAN MACHINIST, 1946, Vol. 90, No. 18, pp. 120-121

4. Details of dial-indicator testing method by which drill-point clearance can be measured accurately; indicator drop readings are taken on 21/32 in. radius pitch circle; angle of clearance is calculated from indicator drop of 5^{o} of drill revolution; clearance angle is measured in plane parallel to axis rather than in plane normal to cutting tip.

   A method of measuring drill point clearance by using a dial indicator. Indicator readings are taken on a 21/32 in. radius pitch circle with the drill being rotated 5^{o} for each reading.

   This clearance angle is measured in a plane parallel to the drill axis instead of normal to the cutting edge.

1. SCHMIDT, A. O. and ROUBIK, J. R.

2. DISTRIBUTION OF HEAT IN DRILLING

3. TRANS. ASME, 1949, Vol. 71, pp. 245-252

4. Using the calorimetric technique, Schmidt and Roubik determined the distribution of the energy generated in drilling. Three different tests were used to determine: 1) total energy dissipated; 2) energy dissipated in the tool; 3) energy dissipated in the chips. The results are shown in Fig. 1.

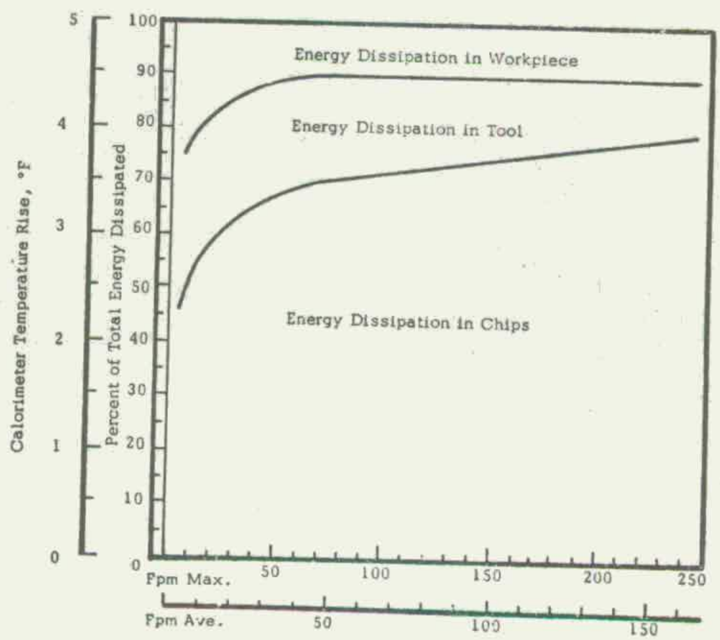


FIG. 1. Distribution of energy in drilling using calorimetric technique.

1. ANONYMOUS

2. DRILLING STUDIES ON TIMKEN ALLOY

3. U.S.A.F. MACHINABILITY REPORT NO. 1, Curtis-Wright Corp., 1950 pp. 106-117

4. The tool-work thermocouple method is pictured in Fig. 1. The tests indicate a relationship between drill temperature and drill life as shown in Fig. 2.

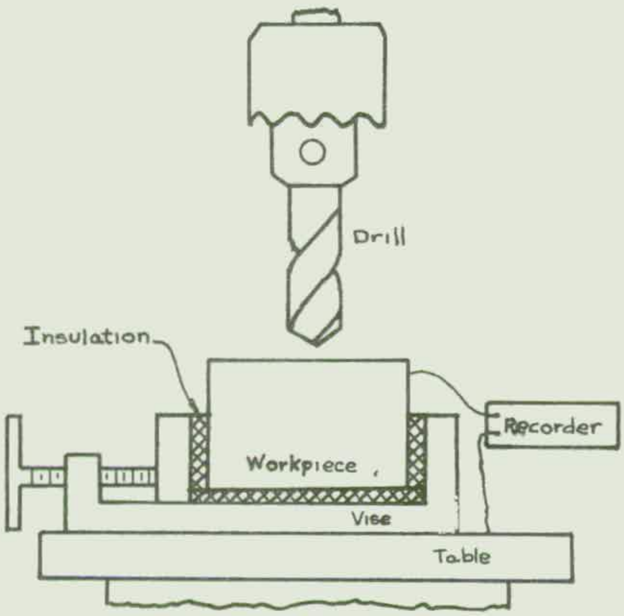


FIG. 1. Schematic of tool-work thermocouple method

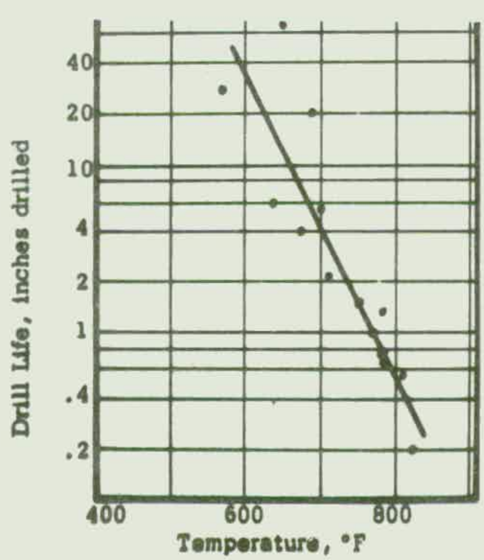


FIG. 2. Influence of drill temperature on drill life

1. LOEWEN, E. G. and SHAW, M. C.
2. DYNAMOMETER FOR MEASURING FORCES ON DRILL
3. INSTRUMENTS, 1950, Vol. 23, No. 6, pp. 560-561
4. Drill dynamometer has no loose or sliding elements, all deflection being purely elastic; built in two parts, upper half designed to measure torque but not thrust while lower half is sensitive to thrust only; by using wire resistance strain gages necessary deflections of dynamometer elements are kept to a minimum.

1. SACK, R. J.

2. HOW TO PRODUCE MORE HOLES WITH YOUR DRILLS

3. MACHINERY, 1951, Vol. 57, No. 9, 10, pp. 143-183, 151-186

4. The essential requirements for obtaining good results in drilling are the use of correctly sharpened drills in efficient drilling machines operating at the most suitable speeds and feeds. Recommended speeds and feeds are shown in Tables 1 and 2. When drilling deep holes (depth 4 x drill diameter) the speed and feed should be adjusted by using the following formulas:

$$\text{Speed} = \text{Normal speed}\left(1 - \frac{\text{Depth of Hole}}{40\text{xDia. of Hole}}\right)$$

$$\text{Feed} = \text{Normal feed}\left(1 - \frac{\text{Depth of Hole}}{50\text{xDia. of Hole}}\right)$$

To reduce the heat generated by friction and increase drill life a cutting fluid should be used.

The use of drill grinding machines is stressed for sharpening drills. Four important factors in drill grinding are:

1) Lip relief angle
2) Equal length of cutting edges
3) Symmetric point angle
4) Web thinning

The minimum relief angle can be found from the following equation:

$$C = \tan^{-1}\left(\frac{f}{2r}\right)$$

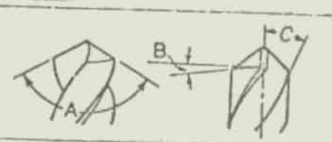
where
f = feed rate (ipr)
r = radius of drill (in.)

The effect of a drill having cutting edges of unequal length or different half-point angles is shown in Fig. 1.

When thinning the web of a drill the thickness should be maintained between 1/8 to 1/10 of the drill diameter.

Aluminum-oxide abrasive wheels of medium structure (No. 5 grain spacing) and medium strength (Grade J to P) are recommended for grinding high speed steel drills. With properly designed grinding machines the use of a coolant is not necessary.

TABLE 1. Suggested speeds, drill angles, and coolants for use in drilling various materials



Material	Cutting Speed,* Surface Feet per Minute	Point Angle *A*, Degrees	Lip Relief Angle *B*, Degrees	Helix Angle *C*, Degrees	Coolant or Cutting Compound	Special Features of Drill
Cast Iron, Soft (150 Brinell Max.)	100–150	90–100	12–15	20–25	Dry or Air Jet	
Cast Iron, Medium Hard (175 Brinell Max.) ..	80–100	90–100	12	20–25	Dry or Air Jet	
Cast Iron, Hard (250 Brinell Max.)	45–80	118–135	7–12	20–25	Dry, Air Jet, or Light Mineral Oil with 5 Per Cent Oleic Acid	
Steel, Mild or Free-cutting	60–120	118	9–15	20–25	Soluble Oil Mixture	
Steel, Alloy	50–80	125–145	7–9	20–25	Sulphurized Oil	
Steel, Alloy, Medium Hard (300 Brinell Max.)	40–60	145	7	20–25	Sulphurized Oil, 3 to 1 Carbon Tetrachloride Mixture	Heavier than standard web
Steel, Stainless (Most Grades)	30–70	125	12	25	Light Mineral Oil	
Steel Rails, 7 to 13 Per Cent Manganese	15–20	136–150	7–10	25	Sulphurized Oil or Dry	Heavier than standard web
Armor Plate	20–45	145	7	20–25	Soluble Oil, Rich Mixture	Heavy web; Short, stubby drill
Aluminum Alloys	200–300	90–130	12–18	17–45	Soluble Oil	Wide polished flutes
Magnesium Alloys ...	200–400	80–118	12–18	10–45	Dry or Mineral Seal Oil	Wide polished flutes
Zinc Die-Castings	300–400	80–136	12–20	10–45	Dry	Wide polished flutes
Monel Metal	40–75	118–145	9–20	20–35	Sulphurized Oil	
Bronze, Soft	100–300	118	12–15	15–30	Dry or Soluble Oil and Water	Lips flattened
Copper and Brass	100–300	100–118	10–15	25–40	Dry or Mineral Seal Oil	Wide polished flutes
Plastics	100–300	60–118	12–15	10–20	Dry or Soapy Water	Wide polished flutes

*Cutting speeds given are for high-speed steel twist drills. Carbon steel drills should operate at speeds of at least 50 per cent less.

TABLE 2. Suggested feed ranges for drilling

Diameter of Drill, Inch	Feed Rate, Inch per Revolution
1/8 and less	0.001 to 0.003
1/8 to 1/4	0.003 to 0.005
1/4 to 1/2	0.005 to 0.008
1/2 to 1	0.008 to 0.016
1 and over	0.016 to 0.025

Note: Use lighter feeds for harder materials and heavier feeds for softer materials.

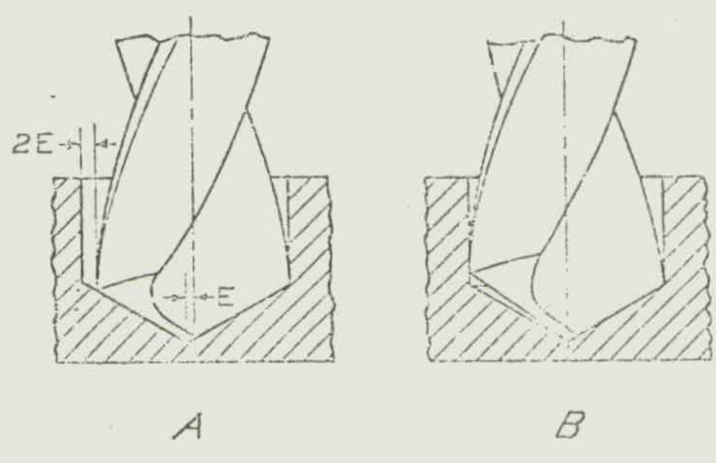


FIG. 1. Hole produced by different lips' length

1. SCHALLBROCH, H.

2. BOHRARBEIT UND BOHRMASCHINE (Drilling and Drilling Machine)

3. PUBLISHER: CARL HANSER VERLAG MÜNCHEN, GERMANY, 1951

4. Drilling forces can be divided not only from thrust and torque, but also one can consider that forces act on the following points:

   a) Lip edge
   b) Chisel edge
   c) Flute
   d) Margin

   Fig. 1 indicates the distribution of forces in connection with feed rate. Fig. 2 shows the percentage distribution of forces on the lip, chisel edge and other points of friction resistance.

   The effect of depth of hole when drilling magnesium-alloyed steel indicated that the torque increased slightly with increased depth of hole(Fig. 3). Remarkable differences were obtained by drills of varied helix angle, where with smaller helix angles the thrust is reduced (Fig. 4).

   The chisel edge length definitely affects the torque and thrust as shown in Fig. 5. Different types of pointing methods have a definite influence on the drill life.

   Fig. 6a shows the comparison of drill life with both regular (Form O) and other pointing methods which are superior in comparison with the regular drill.

   Fig. 6b indicates the advantages of thinned points as compared with regular points. Both torque (Md) and Thrust (A) are relatively small as compared with the regular drill.

   Fig. 7 indicates the total depth of hole for drill failure at varied drilling speeds. Thinned drills (Form I and II) can be run at higher drilling speed as compared with regular drills. (Form O).

   Fig. 8 introduces a schematic illustration of chip formation at both lip edges. The so-called L-v curve, e.g. the length of hole reached by varied feed rates at different drilling speeds, was introduced for a drill dia. of 22 mm in Fig. 9.

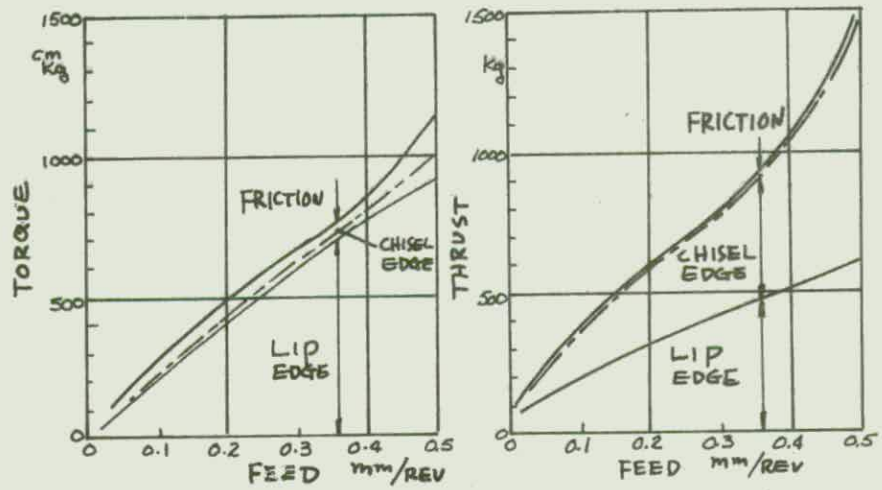


FIG. 1. Distribution of total drilling forces

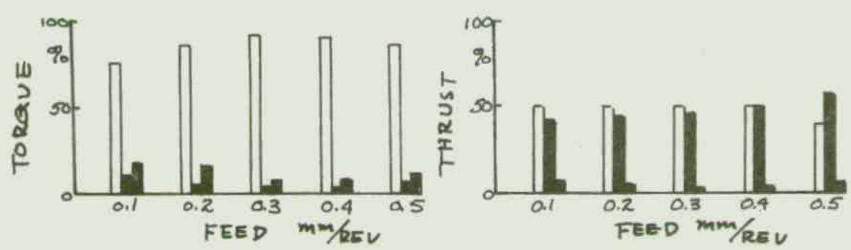


FIG. 2. Percentage of distribution of drill forces

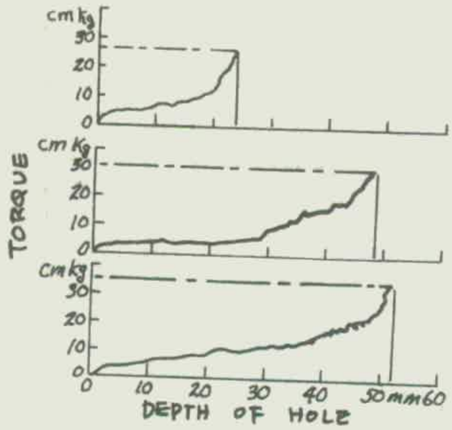


FIG. 3. Effect of depth of hole on torque

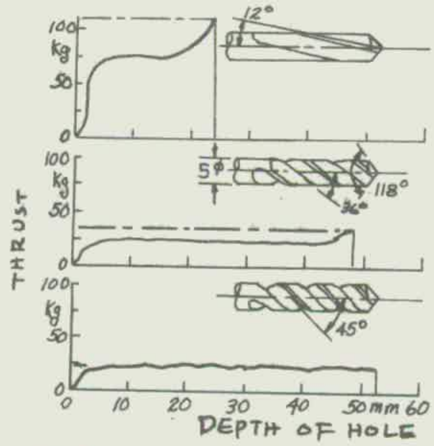


FIG. 4. Effect of depth of hole on thrust

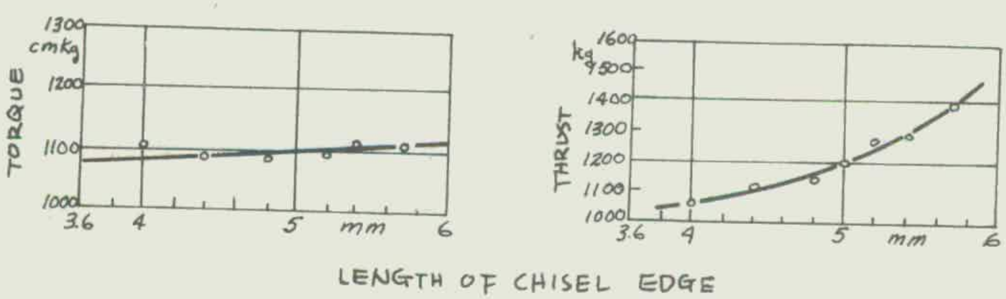


FIG. 5. Effect of length of chisel edge on drilling forces

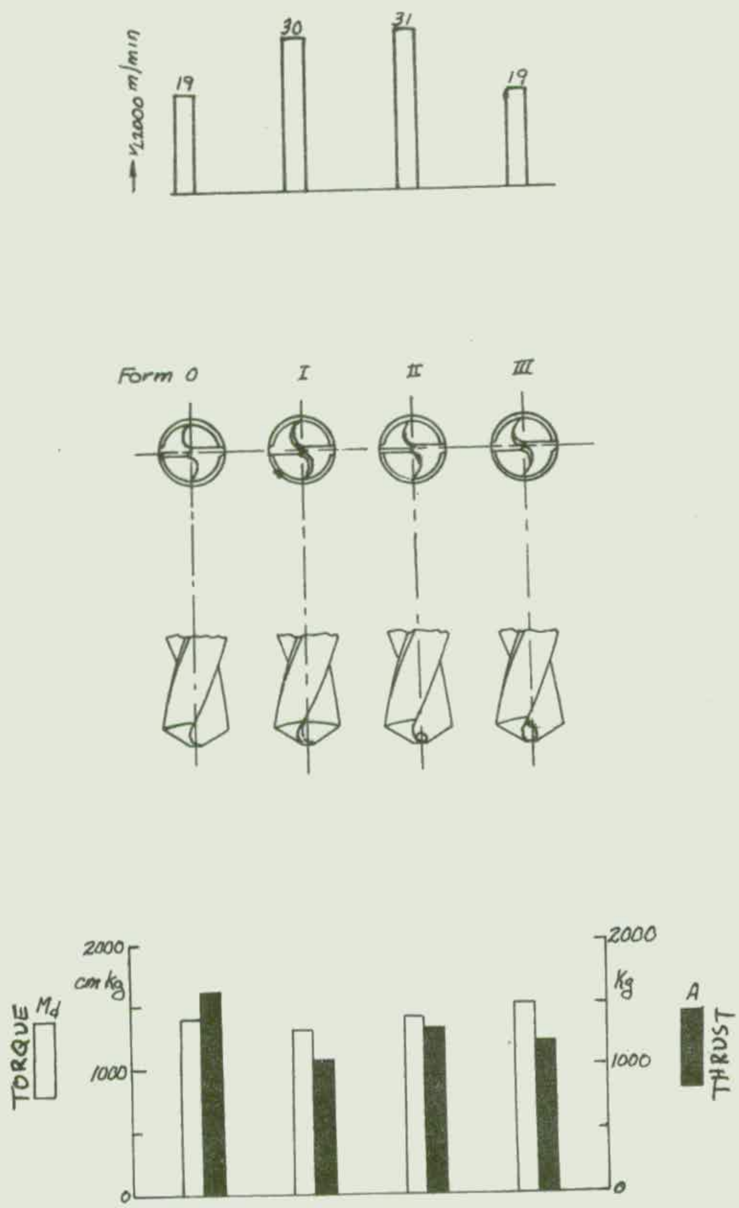


FIG. 6. Comparison of different types of pointing methods in drill life and drilling forces

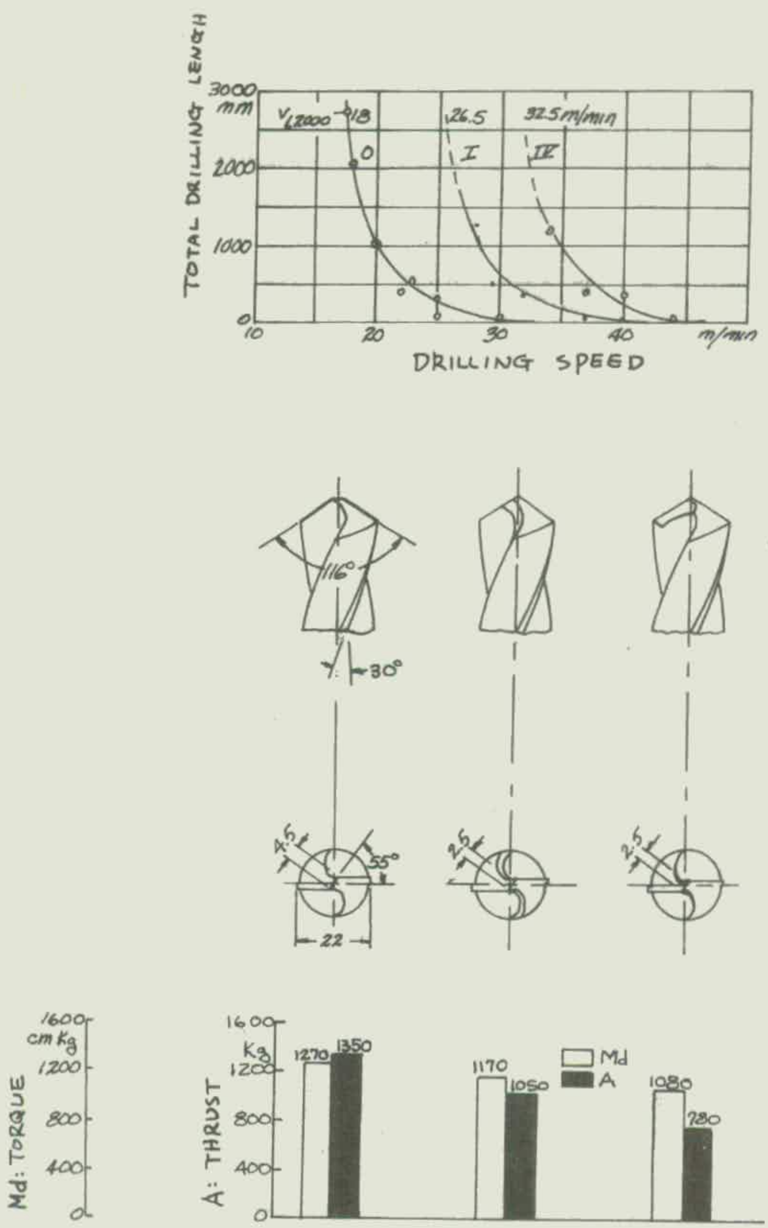


FIG. 7. Comparison of different thinning methods on drill life and drilling forces

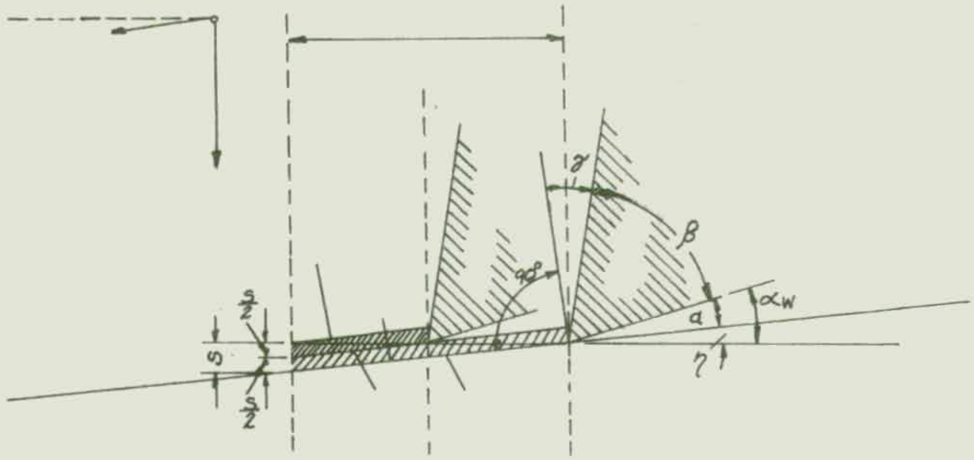


FIG. 8. Schematic illustration of process of chip formation by both lip edges

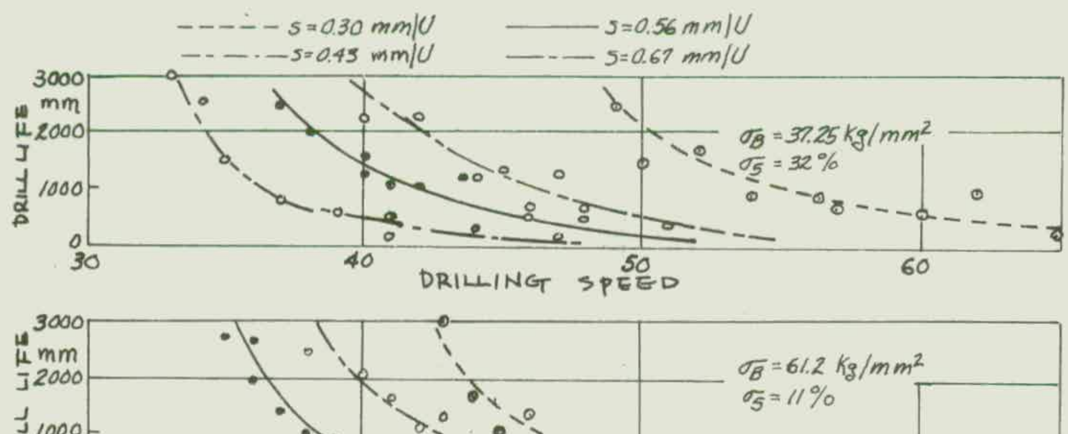


FIG. 9. Relationship between drilling length where drill reaches its life and drilling speed by varied feed rate

1. LICHT, F. W.

2. HOW TO DRILL CAST IRON WITH CARBIDE TIPPED TWIST DRILLS

3. STEEL, June 4, 1951, pp. 92-93

4. Carbide tips are brazed to the ends of regular high speed steel twist drills. The drills have conventional 118 degree point angles with a 12 degree relief angle. In order to remove the excess steel and excess carbide, a 14 degree relief angle should be ground up to a 1/32 in. land (Fig. 1).

   For the best tool life, it is best to start the drilled holes on previously machined surfaces. It is also advisable to drill holes from "the solid" instead of enlarging cored holes in castings. If the cores are shifted the metal removal is uneven (Fig. 2) and the cutting edges near the margin operate on rough, scaly, sandy materials which shortens tool life.

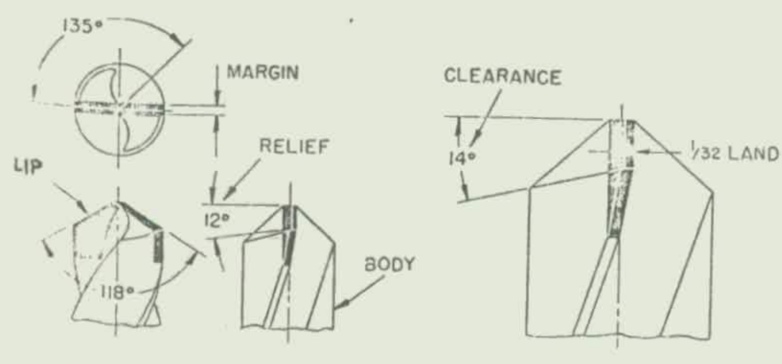


FIG. 1. Carbide twist drill

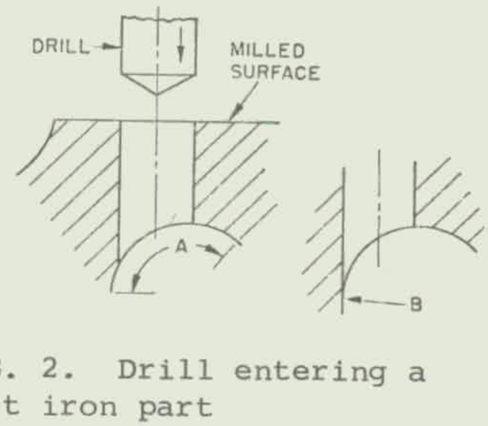


FIG. 2. Drill entering a cast iron part

NOTE: This same article "How to Drill Cast Iron with Carbide Twist Drills" is available from MACHINERY, 1951, Vol. 57, No. 10, pp. 195-197.

1. ANONYMOUS

2. DRILLING CAST IRON AT 260 FEET PER MINUTE WITH CARBIDE TOOLS

3. MACHINERY, 1951, Vol. 58, No. 2, pp. 184-187

4. High cutting speeds, 138 to 260 feet/min., were achieved when drilling cast iron parts by using drills tipped with tungsten-carbide. The drills have special alloy steel shanks to prevent the shank from breaking down behind the tungsten-carbide tips. The drilling is performed without coolant. The average tool life is about 3500 pieces.

1. DICKINSON, T. A.

2. HOW TO DRILL AND RIVET TITANIUM

3. STEEL, 1954, Oct. 18, pp. 96-97

4. When drilling titanium, slow cutting speeds (15-20 fpm) and heavy feed rates (.002-.005 ipr) were used to avoid excessive heat and to minimize work hardening. The drills that were used, Fig. 1, had a point angle of 118 degrees, relief angles of 15 degrees and were thinned.

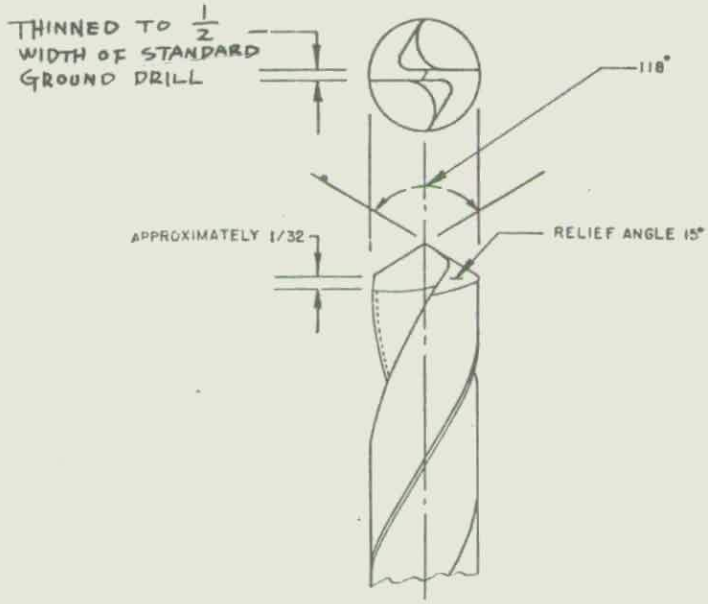


FIG. 1. Special drill bit used in this test

1. PAHLITZSCH, G.

2. EINFLUSS DER STARKKUHLUNG AUF DIE WERKSEUGSTANDZEIT BEIM TIEFLOCHBOHREN MIT SPIRALBOHRERN (Effect of high pressure cooling on the drill life for deep drilling)

3. C.I.R.P. ANNALS, 1954, Vol. 3, pp. 29-33

4. For this investigation, HSS, twist drills of 36 mm (1.4 in.) dia. and 600 mm (15.6") of length were used. When drilling with coolant (emulsion ratio 1:12) in carbon steel with a Vickers Hardness of 60 72, the following results were obtained:

   1) High pressure cooling increased the number of holes between regrinding 2-1/3 times more than regular cooling (Fig. 1).

   2) The economical benefit annually reaches $3,600 for each machine using high pressure cooling system.

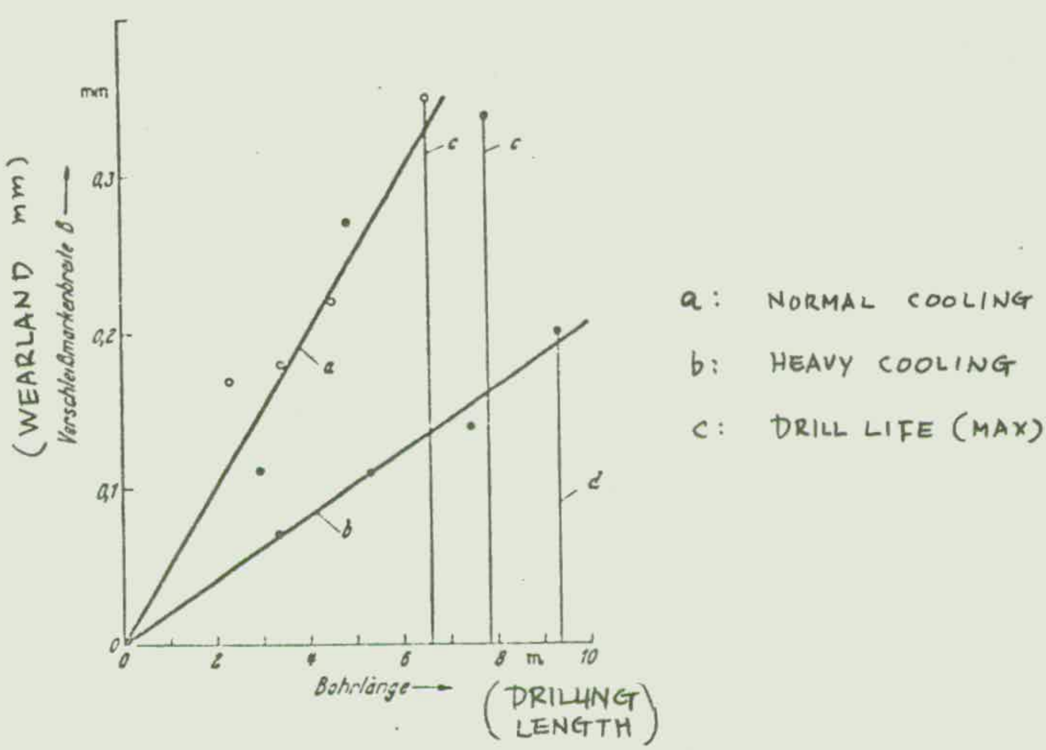


FIG. 1. Drill wear vs.
length of drilled hole

1. GALLOWAY, D. F.

2. ADVANCES IN DRILLING TECHNIQUES ARISING FROM RECENT RESEARCH

3. C.I.R.P. ANNALS, 1954, Vol. 3, pp. 7-13

4. The author has defined the technical criteria in drilling as rate of penetration, drill life, drilling efficiency and the accuracy of the holes. A relation of the main factors in drilling to drill performance is shown in Fig. 1.

An analysis of the various drilling criteria are as follows:

1) Rate of penetration can be expressed as depth of hole drilled per minute and is dependent on the speed and feed used. For the most economical drilling conditions, it is necessary to compromise between drill life and high penetration rates since the high penetration rates lead to an early drill failure as shown in Fig. 2.

2) Drill life can be expressed as the depth of hole drilled between grinds. The difficulty comes in determining a criterion for establishing the end of drill life.

3) The accuracy of the drilled hole is not as important in rough drilling operations as it is in finish drilling where a subsequent reaming operation may be eliminated and scrap reduced.

4) Drilling efficiency can be expressed as the total torque and thrust on the drill.

The effects of various geometric features of a drill on the drill performance were given as:

1) The relative lip height is directly related to drill life as is shown in Fig. 3.

2) The relief angle which provides clearance to prevent rubbing also has an effect on thrust as the angle is varied near the chisel edge (Fig. 4).

3) An increase in the helix angle usually reduces the torque and thrust although it also weakens the cutting edge and may shorten drill life.

4) Cutting fluids are used to cool the drill, lubricate the drill lands and flutes and remove the chips from the hole. Cutting fluids reduce the torque and thrust on the drill with different fluids showing varying reductions.

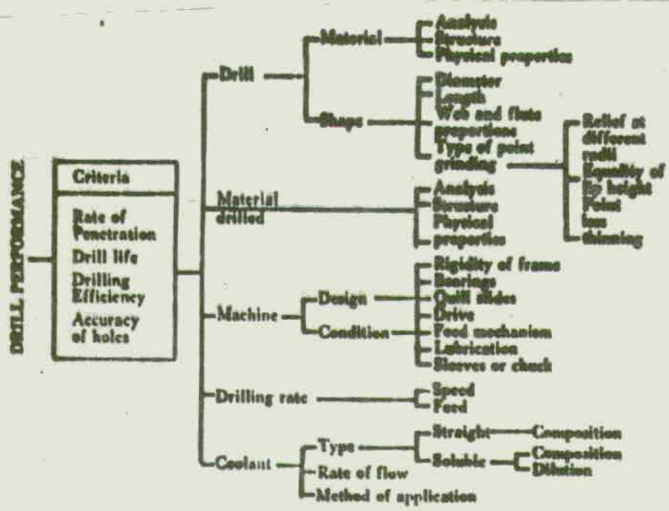


FIG. 1. Criteria and factors for drilling

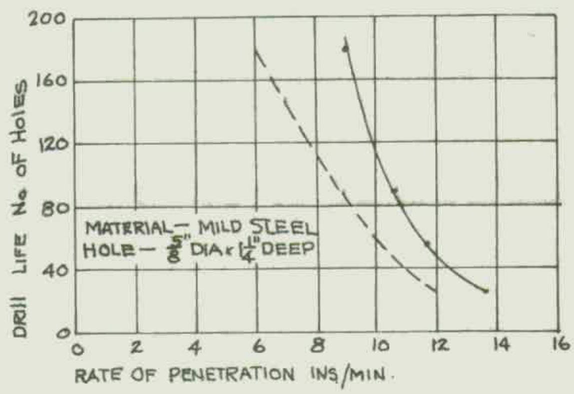


FIG. 2. Relationship between penetration rate and drill life when drilling a mild steel

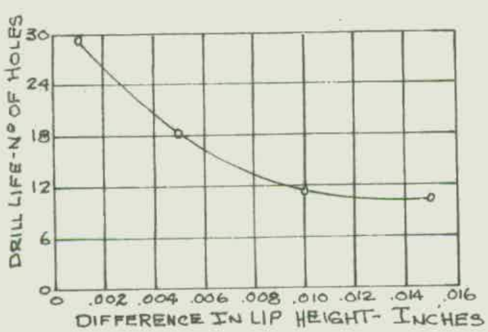


FIG. 3. Influence of relative lip height on drill life

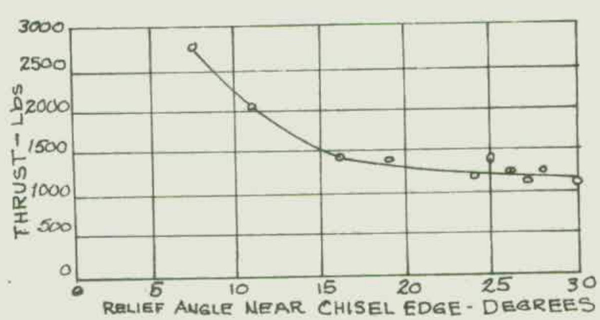


FIG. 4. Influence of relief angle on drill thrust

1. EMDEN, IR. VAN

2. SOUND DRILLING PRACTICE

3. C.I.R.P. ANNALS, 1954, Vol. 3, pp. 14-28

4. Drills from three different manufacturers were checked for variations in geometry, hardness and roughness and were compared. It was found that there were variations in drills from individual manufacturers as well as marked differences in the drills from the different manufacturers. The author concluded that:

    1. There is a lack of correlation between dimensions, physical properties and drill performance.

    2. It is impossible to compare drills of different makes with respect to cutting ability.

    3. Drills should be ground on a drill grinding make that is kept in good condition.

    4. The workpiece should be properly clamped.

    5. The correct speed and feed should be selected from a table.

    6. An ample supply of coolant should be used.

1. ANONYMOUS

2. NEW DRILL ANGLES FOR TITANIUM

3. AMERICAN MACHINIST, 1954, Vol. 98, No. 13, pp. 142-144

4. Drilling titanium with conventional drills using hand-held portable tools produced poor hole quality and short drill life. The drills often failed after 3 to 6 holes and the holes were often triangular shaped.

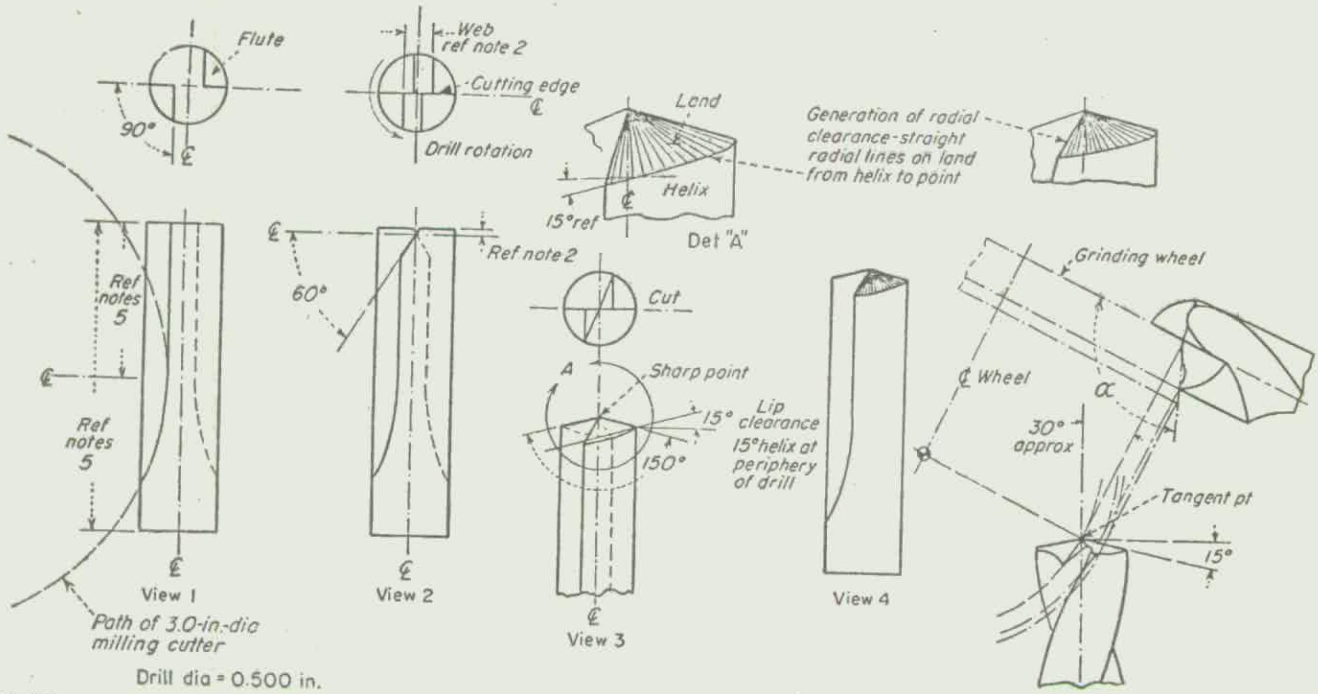
   A drill that was designed to overcome these difficulties had the following specifications:

   1.) Short length - straight or spiral flute
   2.) 150 degree point angle
   3.) No body clearance
   4.) Zero degree rake angle
   5.) The web is cleared to the drill center removing the chisel edge
   6.) Both cutting edges are in one line and meet at the center
   7.) Generated lip clearance insures clearance all the way to the center

   The set-ups for grinding the drills is shown in Fig. 1.

   Drilling was done at 485 to 500 RPM for drills from No. 40 through 5/16 in. diameter. Dry drilling up to two diameters proved practical.

   The drills were coated with a black oxide finish to prevent galling and pickup of titanium. Conventional drills and the special drills with and without the black oxide finish are compared.



NOTES

1. *To determine web thickness, multiply drill diameter by 0.364 (straight-flute drill only.)*
2. *Sufficient stock to be left for cutting-edge grind.*
3. *All surfaces in contact with work to be black-oxide finished.*
4. *Drills to have no body clearance.*
5. *Drill over-all length & flute length to conform to standards for screw-machine short-length drills.*
6. *Rake angle to be 0° on both straight & spiral-flute drills.*

SETUP FOR GRINDING STRAIGHT AND SPIRAL-FLUTE DRILLS

FIG. 1

1. OXFORD, C. J., JR.

2. ON THE DRILLING OF METALS (1) BASIC MECHANICS OF THE PROCESS

3. TRANS. ASME, 1955, February, pp. 103-114

4. In order to study the formation of chips under the cutting edge Oxford developed a quick-stop mechanism, Fig. 1, to give rapid stop of the relative motion between the drill and workpiece. After the drill and workpiece came to rest the drill was carefully screwed out of the hole leaving the chips attached to the bottom of the hole.

   The specimens were sectioned along desired planes and the chip formation observed. The chips were observed. The chips were observed to be similar to those formed by other metal cutting operations. A specimen of a drilling chip is shown in Fig. 2.

   The cutting action under the chisel edge is more complex. Under the exact center of the drill the deformation is similar to that made by an indenting punch. This is shown in Fig. 3. When this chip is ejected into the drill flute space it is usually carried off on the chips formed by the cutting edges. The chisel edge chip is sometimes ejected as a separate ribbon-like chip.

   At a radius of 0.037 in., Fig. 4, the cutting action is similar to a tool with a high negative rake angle.

   Specimens were sectioned and the apparent chip flow angle, η_ρ, was measured with a toolmaker's microscope. This apparent chip flow angle is converted to the true chip flow angle, η, along the flute by the relationship

$$\tan \eta = \tan \eta_\rho \cdot \cos \alpha_f$$

   where α_f is the face rake angle.

   The inclination angle, i, of a drill is given by

$$\sin i = \sin \beta \sin \rho$$

   and is shown in Fig. 5.

   The relationships for chip flow angle, η, versus inclination angle, i, is shown in Fig. 6 for five specimens.

The effective rake angle had been previously defined as

$$\sin \alpha_e = \sin \eta \sin i + \cos \eta \cdot \cos i \cdot \sin \alpha_n$$

This has been calculated for different drill designs (point angle and web thickness) and cutting conditions with the results shown in Fig. 7 and 8.

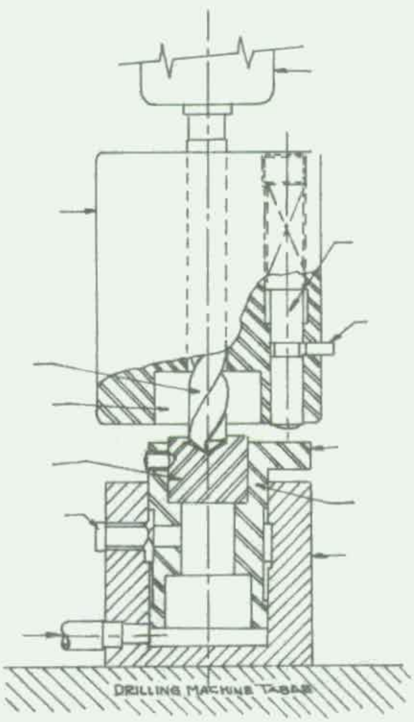


FIG. 1. Quick stop mechanism

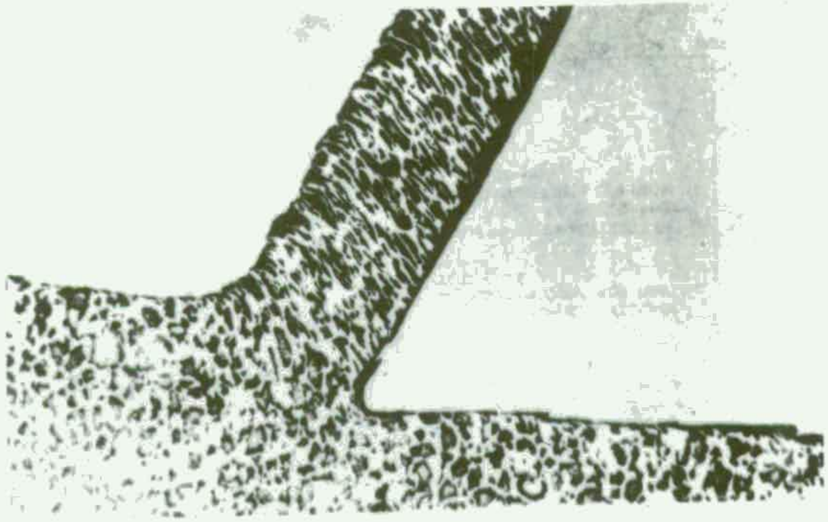


FIG. 2. Photomicrograph of a drilling chip at a 0.335 in. radius on a 3/4 in. diam. drill

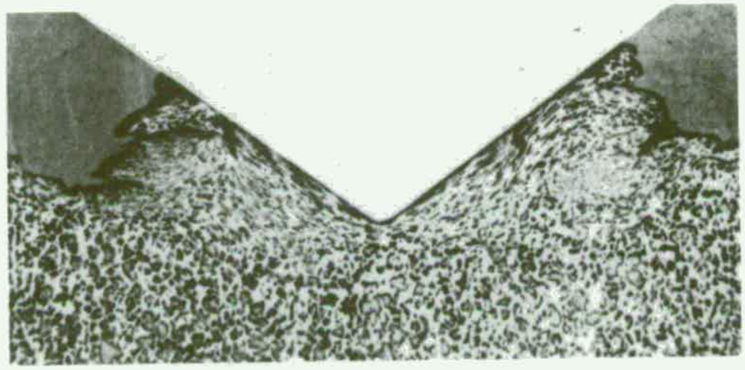


FIG. 3. Photomicrograph of chip at the center of the drill normal to the chisel edge

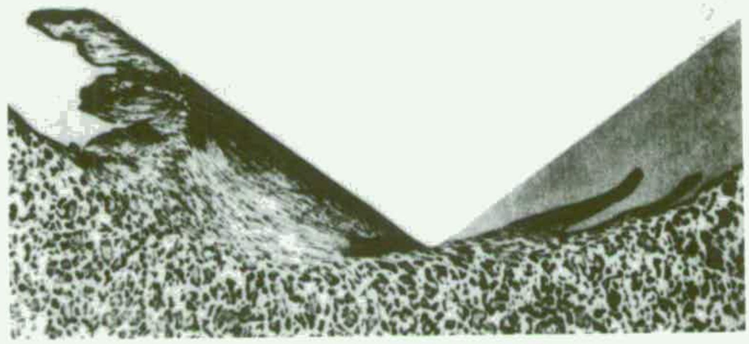


FIG. 4. Photomicrograph showing a high negative rake angle (56 deg.) at 0.037 in. radius, 3/4 in. drill

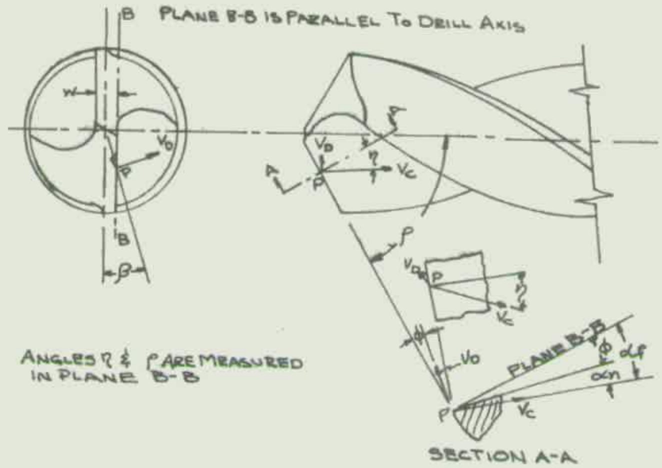


FIG. 5. Diagram of drill point showing inclination angle, i

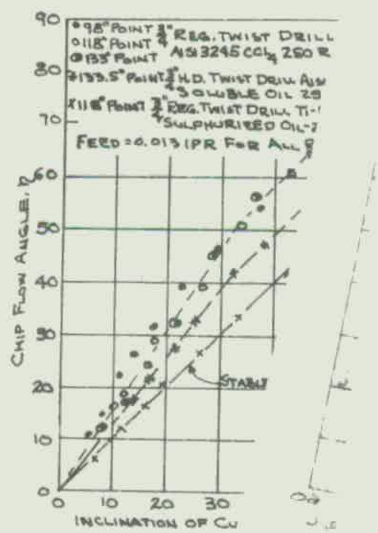


FIG. 6. Relationship of chip flow angle, η, to inclination angle i

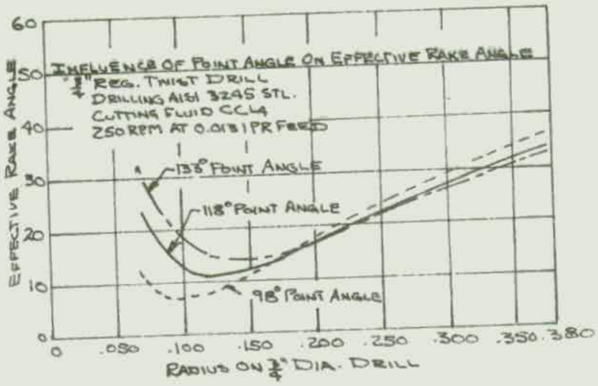


FIG. 7. Effect of drill point angle on effective rake angle at different radii

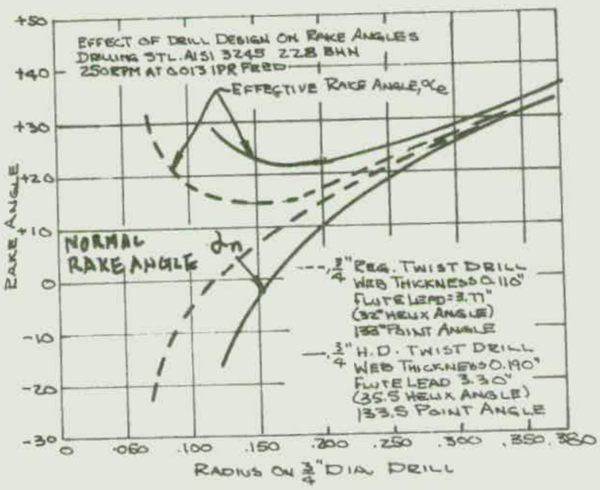


FIG. 8. Effect of drill design on rake angle at varying radii

1. DANIELYAN, A. M.

2. EFFECT OF SHAPE OR FORM OF GRINDING OF DRILLS ON TEMPERATURE AND CUTTING FORCES

3. VESTNIK MASHINOSTROENIYA, 1955, Vol. 35, No. 11, pp. 48-51

4. Using a tool-work thermocouple, the author has shown the relationship, Figs. 1 and 2, between drill temperature and speed and feed.

The area of the graph, Fig. 1, where the temperature is practically constant is where the chips began to break up providing for easier ejection.

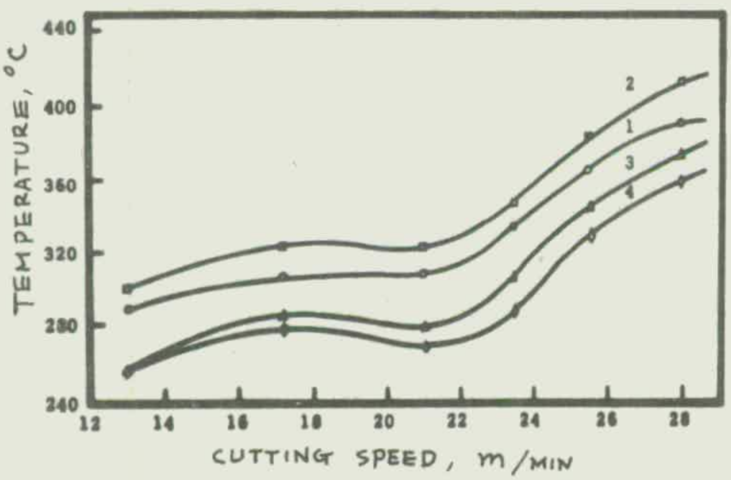


FIG. 1. Temperature vs. cutting speed

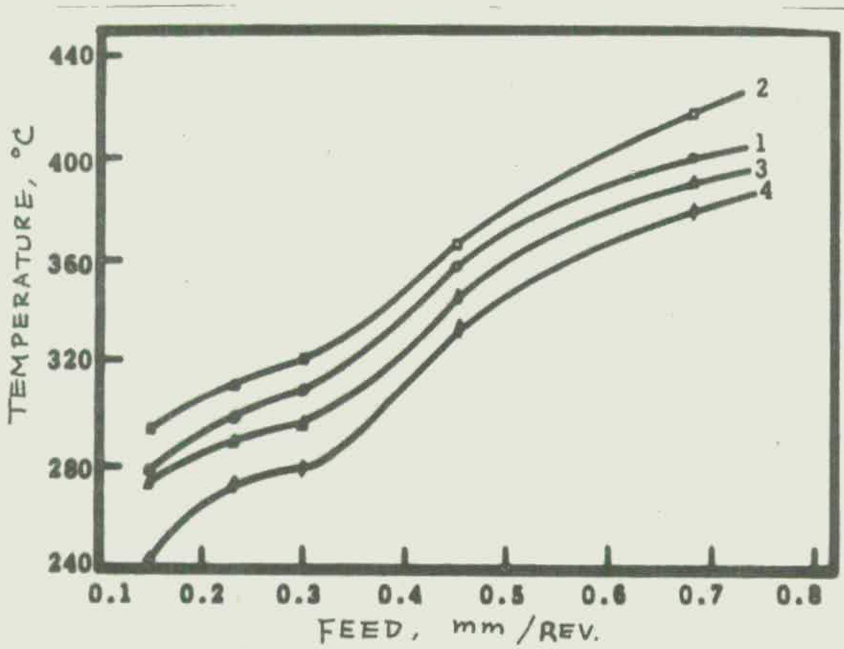


FIG. 2. Temperature vs. feed rate

1. WICK, C. H.

2. CONSTANT RESEARCH INSURES BETTER CUTTING TOOLS

3. MACHINERY, 1955, Vol. 61, No. 11, pp. 137-142

4. A quick stop device for eliminating the relative motion between the drill and the workpiece is shown in Fig. 1. This apparatus allows the formation of the chip to be studied.

   The chip formation was found to be similar to that of other metal cutting operations except for the zone under the chisel edge.

   Under the chisel edge what appears to be a severe built-up edge acts to make the cutting rake more positive. The deformation at the center resembles that of an indenting punch and yields a highly deformed ribbon chip which escapes into the drill flute.

   Although the chisel edge region removes only 3% of the metal and requires very little additional power 50 to 65% of the thrust force is developed there.

   Drill life tests conducted over a seven year period on SAE 3245 (BHN 228) show that the drill life approximates a normal distribution.

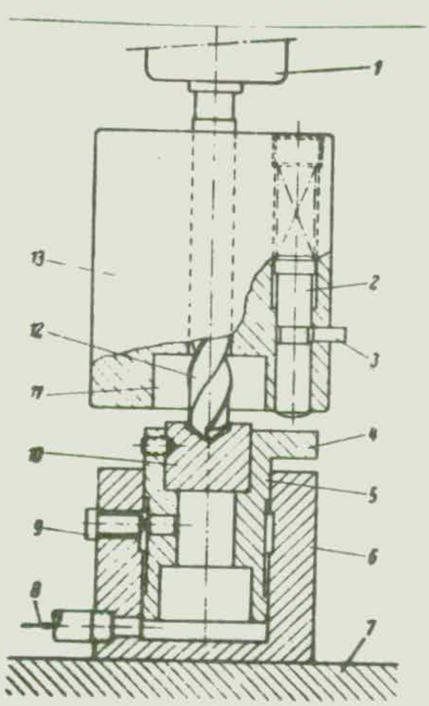


FIG. 1. Quick stop device

1. OXFORD, C. J., JR.

2. SOME RECENT RESEARCH ON TWIST DRILLS AND DRILLING

3. TECHNICAL PAPERS AND PANEL CONFERENCES, Presented at 23rd Annual Meeting, 1955, American Society of Tool Engineers, 1955, pp. 1-8

4. An important variable affecting drill life is the length of the drill. When drilling S-816 cobalt base alloy the drill life was increased 80 times by reducing the flute length from 2-7/8 in. to 1-11/16 in. (Fig. 1).

   The amount of hole oversize to be expected when drilling steel and cast iron is shown in Fig. 2. For drills in the 1/8 in. to 1 in. diameter range, the following relations can be used to predict the hole oversize:

   Average Oversize = 0.002 + .005D
   Maximum Oversize = 0.005 + .005D
   Minimum Oversize = 0.001 + .003D

   where D = drill diameter in inches

   With good drill sharpening equipment and good drilling equipment the minimum oversize may be expected, while with poorly ground drills and poor equipment the maximum oversize will be approached.

   Although it is difficult to accurately determine the point of drill failure repeatedly a series of tests run over a seven year period show that the life points approximate a normal distribution (Fig. 3).

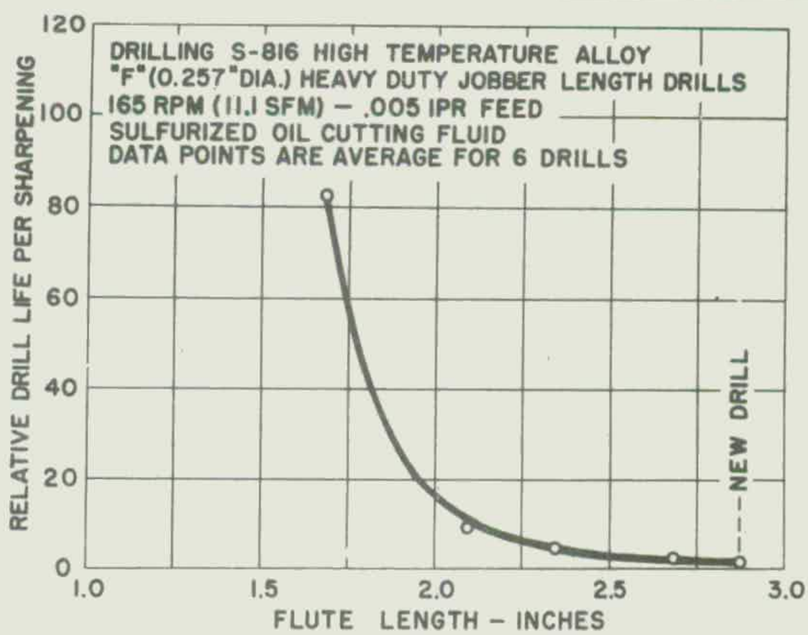


FIG. 1. Effect of drill length upon drill life

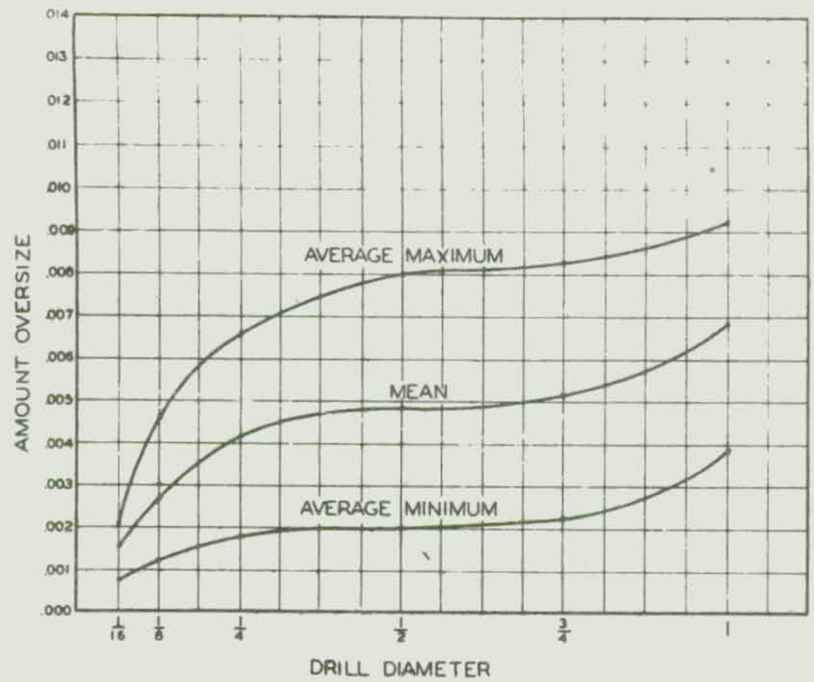


FIG. 2. Oversize of drilled holes

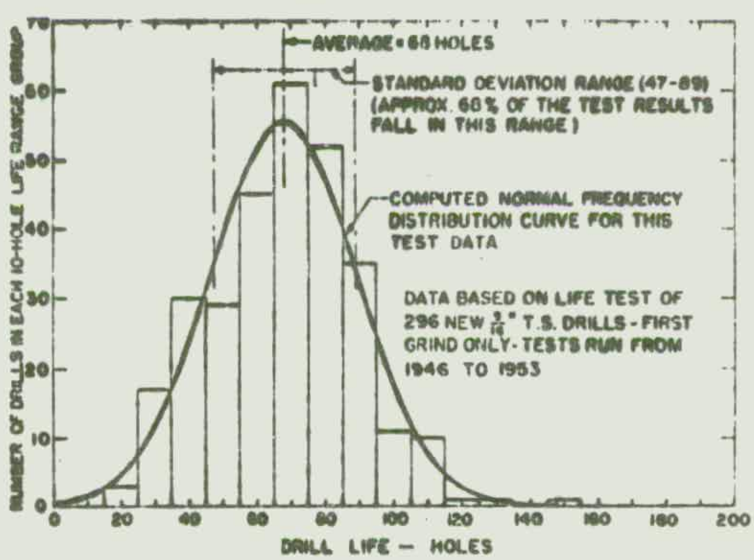


FIG. 3. Histogram of drill life

1. OXFORD, C. J., JR.

2. PRODUCING ACCURATE HOLES

3. MACHINERY, 1956, Vol. 62, No. 7, pp. 186-189

4. To produce holes that are straighter and closer to size, double-margin drills (Fig. 1) are recommended. The extra margins are located approximately midway between the primary margins and thus provide four guide points. The extra margins help to eliminate the effects of errors in point grinding.

   Double-margin step drills (Fig. 2) can also be used.

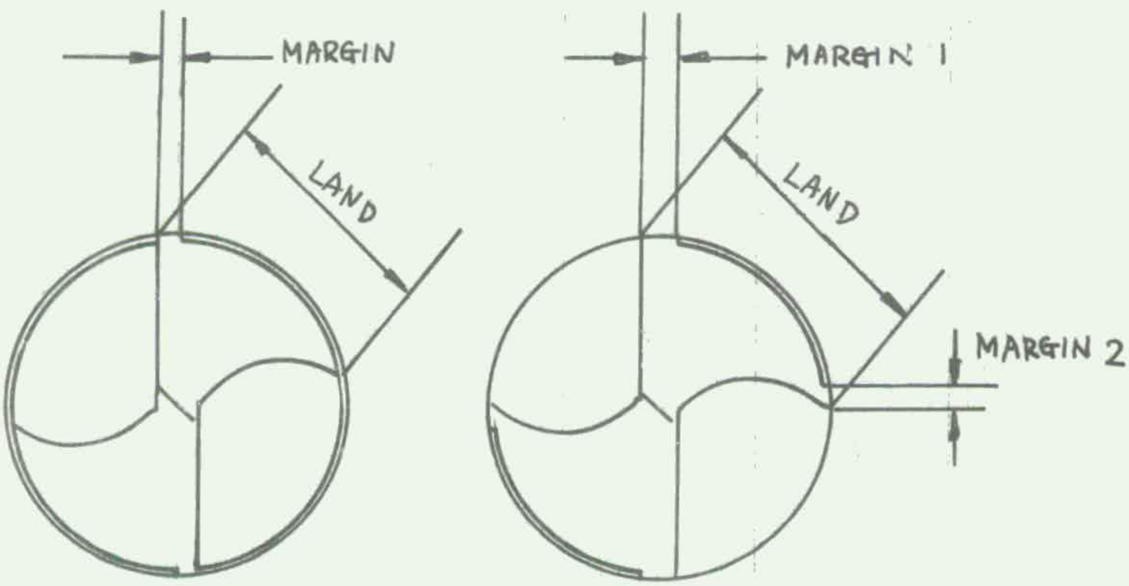


FIG. 1. Regular and double margin drill

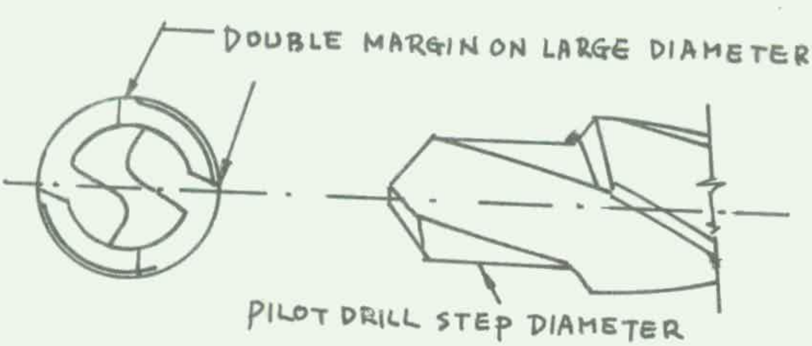


FIG. 2. Double margin step drill

1. ANONYMOUS

2. NEW SPIRAL POINT BOOSTS TWIST DRILL EFFICIENCY

3. IRON AGE, 1957, Vol. 180, No. 16, pp. 115-117

4. Drill developed by Cincinnati Milling Machine Co. uses true self centering point and S shaped cutting edge in place of conventional chisel point; drills ground to new design last longer, produce rounder, straighter, on-size holes, require no center punching, etc.; combination of high negative rake and low speed at point of axis produces low shear angle with resultant high thrust force; special grinder can be adjusted to vary drill point angle from 90 to about 180°.

   Comparison of spiral point drill with chisel point regarding oversize is shown in Fig. 1.

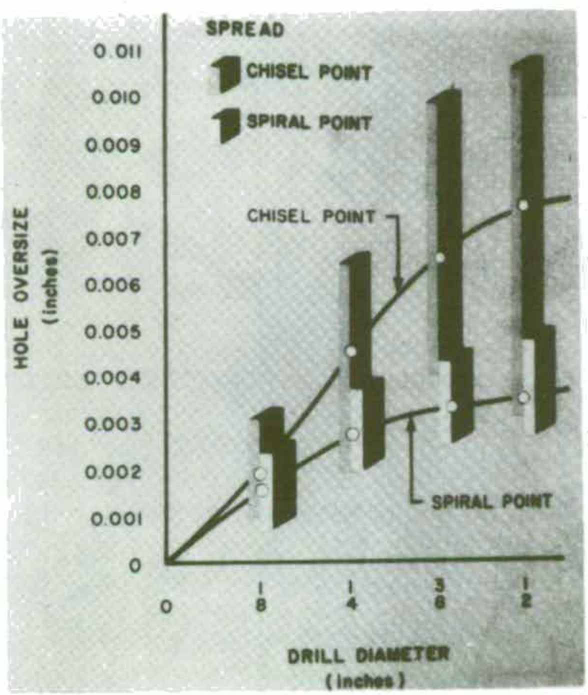


FIG. 1. Oversize of holes produced by chisel point drills compared with the oversize produced by spiral point drills

1. GALLOWAY, D. F.

2. SOME EXPERIMENTS ON THE INFLUENCE OF VARIOUS FACTORS ON DRILL PERFORMANCE

3. TRANSACTIONS OF ASME, February, 1957, pp. 191-231

4. Through the author's extensive research, the principal technical criteria and factors of drilling were established as shown in Fig. 1.

   Referring to Fig. 2, the author mathematically analyzed drill geometry as follows:

   (1) Normal relief angle along the lips, ,

$$\tan\alpha = \frac{\tau}{\rho}\left[1-\left(\frac{\rho^2-\tau^2}{1-\tau^2}\right)^{\frac{1}{2}}\right]\cot K + \frac{1}{\rho}\left(\frac{\rho^2-\tau^2}{1-\tau^2}\right)^{\frac{1}{2}}\tan\alpha_o$$

where α = Normal relief angle at any point P on lip

α_o = Normal relief angle at outer corners

K = ½ point angle

$\rho = \dfrac{\text{radius r at P}}{\text{radius R at outer corners}}$

$\tau = \dfrac{\text{web thickness 2t}}{\text{radius R at outer corners}}$

The variation in normal relief angle along the lip of different sized drills is shown in Fig. 3.

   (2) Angle between drill axis and cone axis

$$\cos\chi = \frac{\sin\psi\cdot\sin K\cdot\sin\theta}{(\sin^2\psi+\cos^2\psi\cdot\cos^2 K)^{\frac{1}{2}}} + \cos K\cdot\cos\theta$$

where θ = semiangle of grinding cone

f = distance between cone axis and drill axis

g = projected distance between cone vertex and drill axis on to a plane parallel to cone axis and drill axis

(3) Relationship between ψ and the normal relief angle, α_o

$$\cot\psi = -\frac{1}{(1-\tau^2)^{\frac{1}{2}}}\left[\tan\kappa\cdot\tan\alpha_o - \tau\right]$$

(4) Relationship of normal relief angle to angle between machined and flank surfaces

$$\tan\alpha_n = \frac{\left[\tau\{(1-\tau^2)^{\frac{1}{2}}-(\rho^2-\tau^2)^{\frac{1}{2}}\}\cos\kappa+(\rho^2-\tau^2)^{\frac{1}{2}}\cdot\sin\kappa\cdot\tan\alpha_o\right]}{\{(1-\tau^2)^{\frac{1}{2}}(\rho^2-\tau^2)^{\frac{1}{2}}+\tau^2\cos^2\kappa-\tau\sin\kappa\cdot\cos\kappa\cdot\tan\alpha_o\}}$$

(5) Relationship between γ_a and drill helix angle γ_o

$$\cot\gamma_a = \frac{1}{(\rho^2-\tau^2)^{\frac{1}{2}}}(\rho\cot\gamma\cdot\sin\kappa-\gamma\cos\kappa)$$

(6) Relationship between normal rake γ_n, and drill helix angle γ_o

$$\tan\gamma_n = \frac{\rho^2-\tau^2\sin^2\kappa}{(\rho^2-\tau^2)^{\frac{1}{2}}\sin\kappa}\cdot\tan\gamma_o-\frac{\tau}{(\rho^2-\tau^2)^{\frac{1}{2}}}\cdot\cos\kappa$$

The research results can be summarized as follows:

(1) There was a different range of point angle which gave the longest drill life for each material (Fig. 4). Also, the optimum normal relief angle for the materials tested was found to be between 9 and 15 degrees as shown in Fig. 5.

(2) The author found that various methods of point thinning affected drill life (Fig. 6).

(3) It was pointed out that relative lip height is one of the commonest faults in drill grinding and that excessive relative lip height can substantially reduce drilling efficiency. The result in Fig. 7 shows that drill life was increased nearly three times by reducing the relative lip height for a 5/8 in.-dia. drill from 0.015 to 0.001 in.

(4) Hole accuracy is markedly dependent on the symmetry of the drill point. A common error in symmetry is shown in Fig. 8. The hole oversize increases linearly with the relative lip height, and the oversize for a given relative lip height is less with smaller point angles as shown in Fig. 9.

(5) Using capacitive gages, the continuous records of point displacement for a drill and a contactor on the machine spindle which injected a pulse to mark the position of the outer corner along the trace, were presented in Fig. 10a which shows a trace for 6 revolutions of a drill, along with the inner and outer boundary diagrams.

Figs. 10b, c, d and e convey the essential information derived from the drill point deflection record, with or without center hole, for different relative lip heights.

(6) Because of the initial drill deflections, the axis of the drill point becomes inclined to the spindle axis and, with increasing depth, the deflection and slope become progressively larger, so that the path of the drill tends to wander further and further from the true axis. An example of the relationship between the slope of a drilled hole and the displacement of the top of a hole from the spindle axis is shown in Fig. 11.

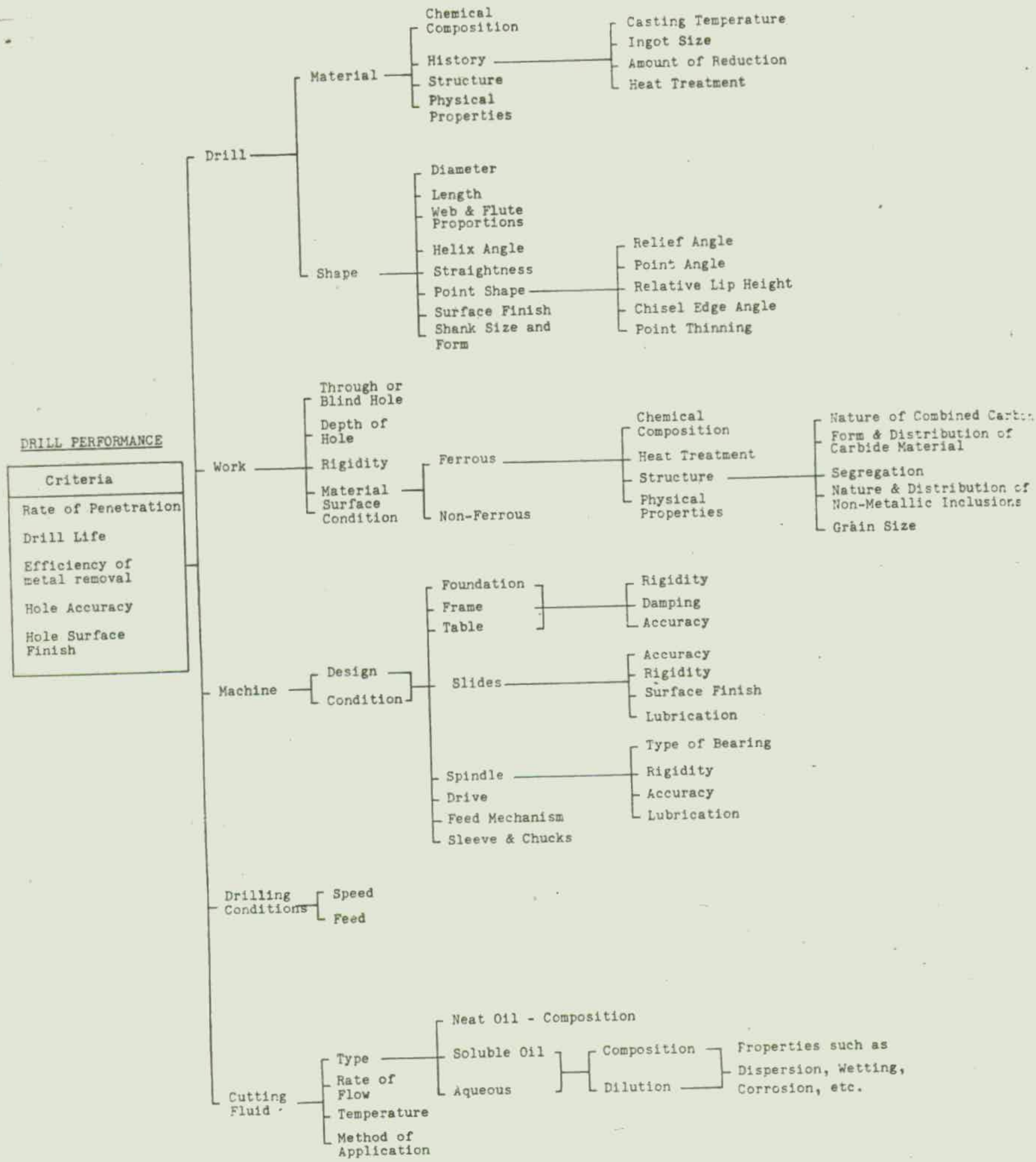


FIG. 1. Principal technical criteria and factors involved in drilling

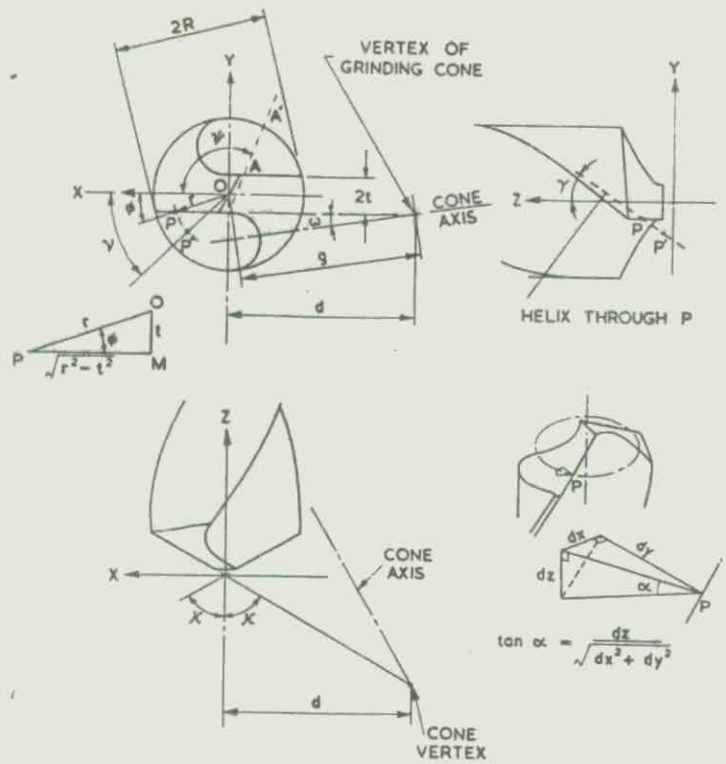
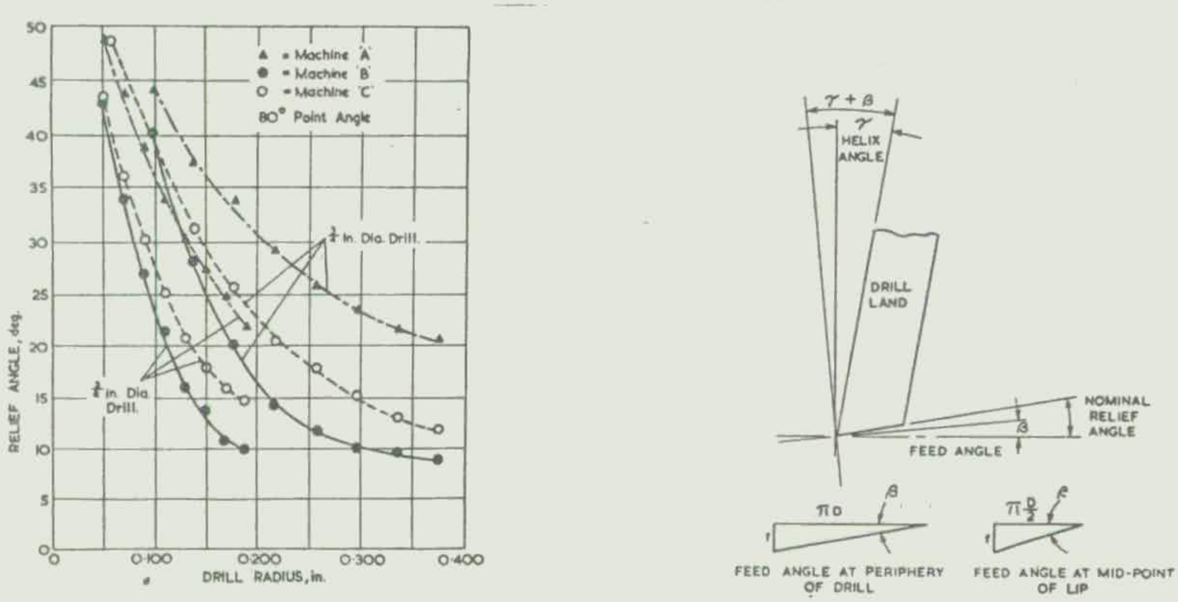


FIG. 2. Views of drill point



(a) Measured values of relief angle for 80-deg point angle drills ground on three machines

(d) Effect of feed on angles at drill point

FIG. 3. Relief and feed angles along drill lips

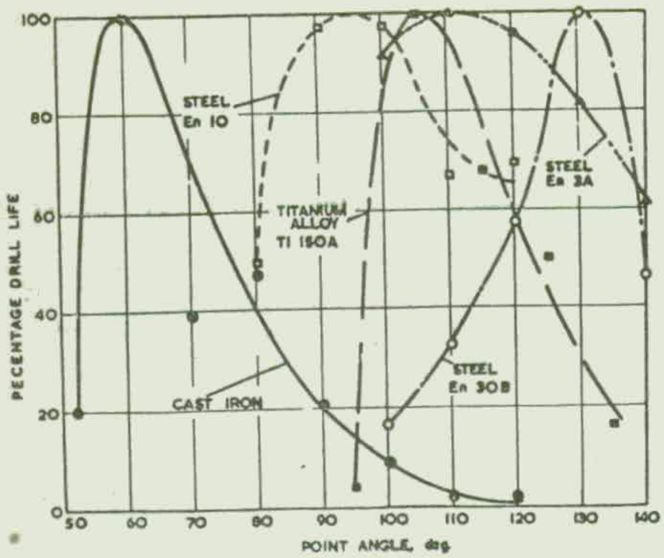


FIG. 4. Effect of point angle on drill life in various materials

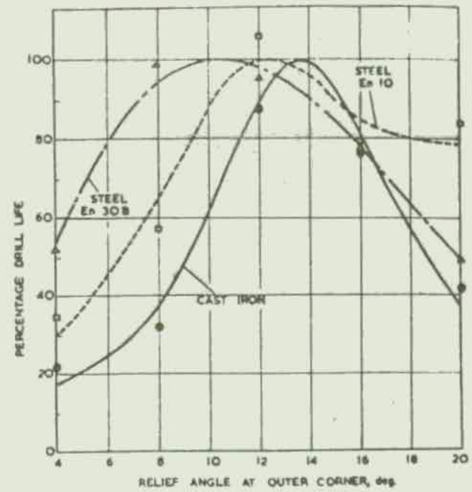
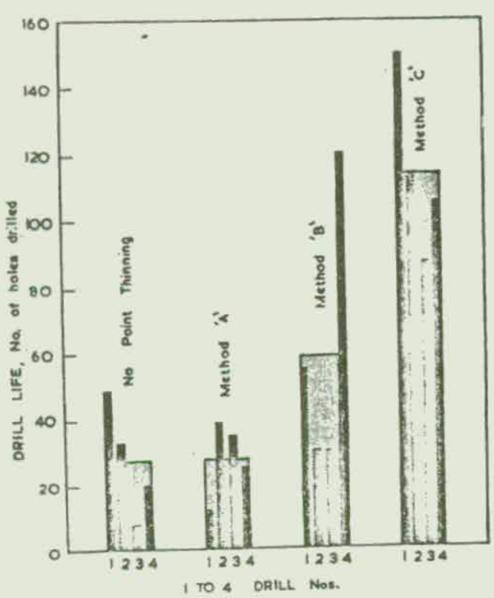


FIG. 5. Effect of relief angle on drill life in various materials



(a) Results of drill-life tests

Drill diam.	$^5/_8$ in.	Spindle speed	945 rpm
Helix angle	28°	Feed	0.0135 in./rev
Point angle	118°	Cutting fluid	soluble oil
Relief angle	$10^1/_2$°		

FIG. 6. Effect of various methods of point thinning on drill life

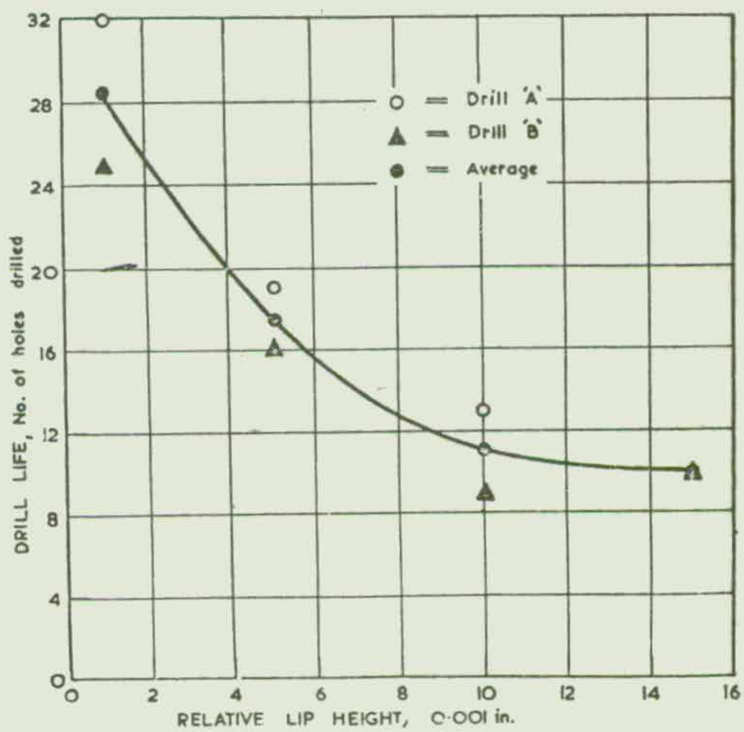


FIG. 7. Effect of relative lip height on drill life in steel EN 12

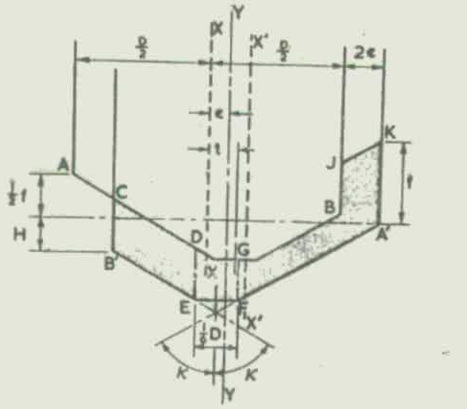


FIG. 8. Position of axis of drill rotation

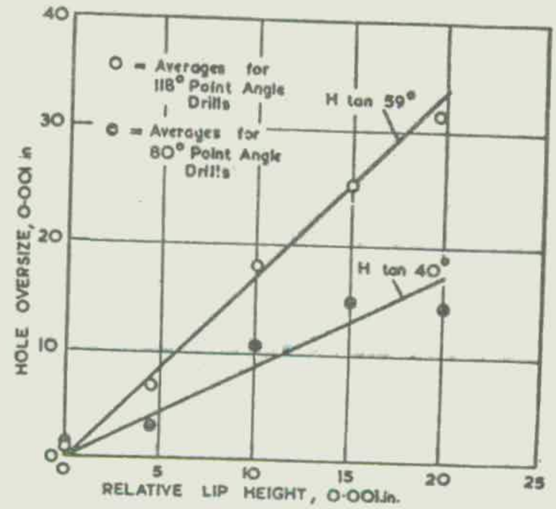


FIG. 9. Effect of relative lip height on hole accuracy

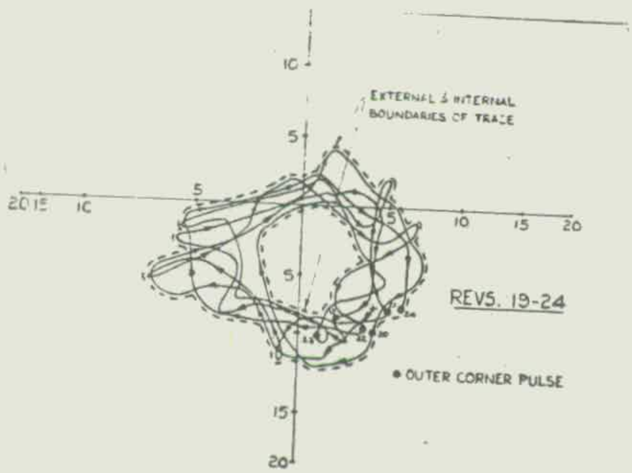


FIG. 10a. Derivation of boundary diagrams from deflection records

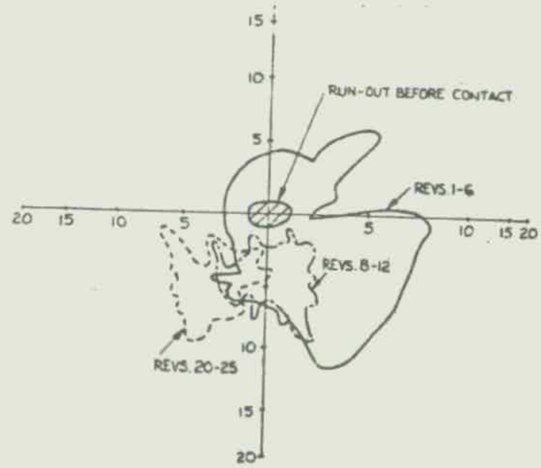


FIG. 10b. Relative lip height < 0.001 in. without center hole

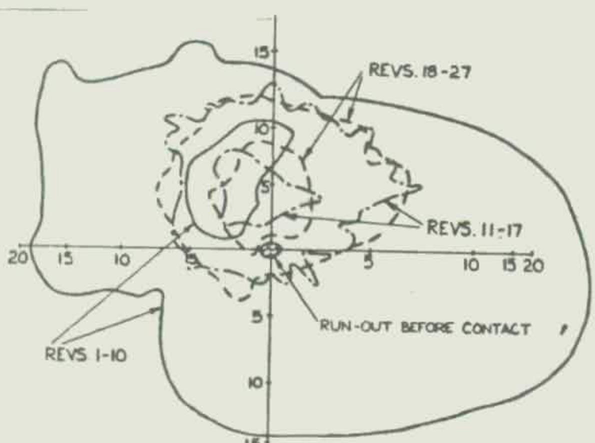


FIG. 10c. Relative lip height: 0.005 in. without center hole

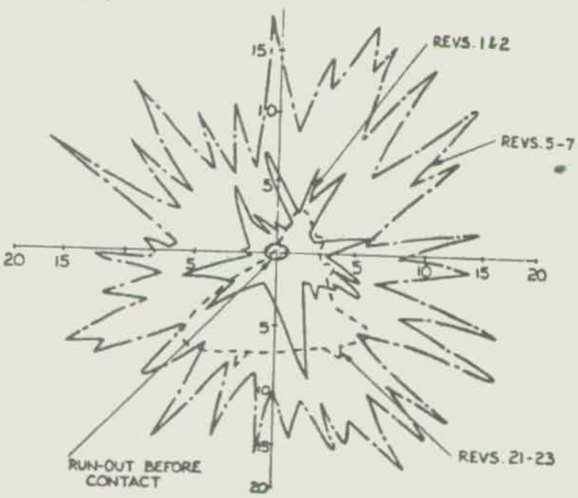


FIG. 10d. Relative lip height < 0.001 in. with center hole

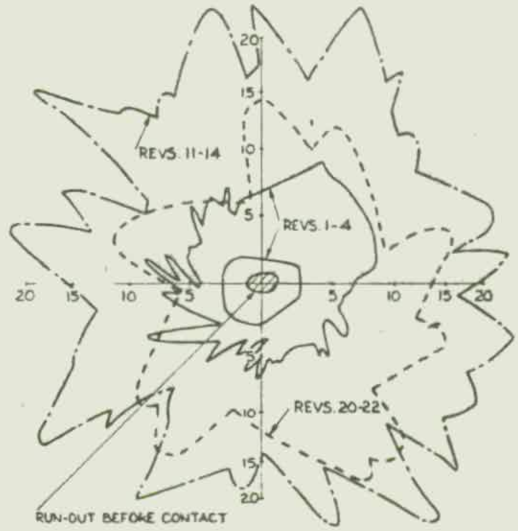
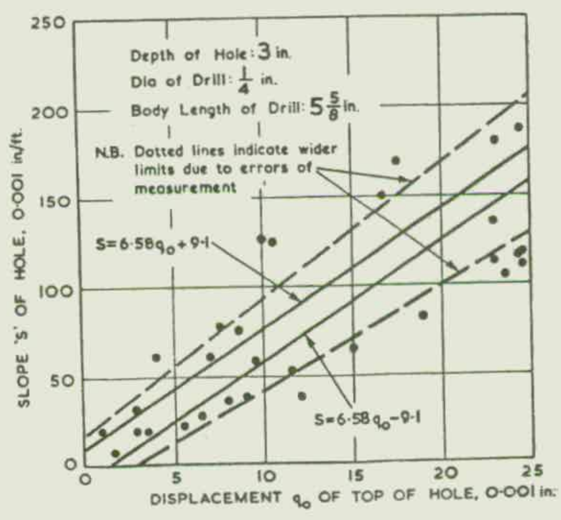


FIG. 10e. Relative lip height: 0.005 in. with center hole



(a) Results for 1/4-in-diam drill

FIG. 11. Relationship between slope of drilled hole and displacement of top of hole from spindle axis

1. KLEIN, H. H.

2. DAS BOHRSCHAUBILD ALS KRITERIUM DER BOHRERFORM UND -LEISTUNG (Criterion of drill form and performance)

3. WERKSTATTSTECHNIK UND MASCHINENBAU, 1957, Vol. 47, No. 11, pp. 597-603; Also, ENGINEERING DIGEST, Vol. 19, No. 1, 1958, pp. 7-10

4. It was possible to measure drilling force to record and their progress during drilling using both the dynamometer (Fig. 1) and the light-point recorder (Fig. 2) which were developed by the Technical University of Aachen, Germany and the firm of Hartmann and Braun, Germany, respectively. An example of a cutting force diagram in drilling in a filled workpiece is shown in Fig. 3.

   Two drilling force diagrams were introduced. One has a 1.5 mm diameter, 6 mm deep predrilled hole (Fig. 4) and the other was obtained when drilling a workpiece which was predrilled 6 mm in diameter and 10 mm deep (Fig. 5).

   The chip breaker drill was compared with a regular drill in the drilling force diagram in Fig. 6 (a) is with chip breaker, b) is without chip breaker).

   The effect of lip clearance angle (Fig. 7) and point angle (Fig. 8) were also introduced. The exponent for the feed rate is shown in Fig. 9. Increased wearland on the lip produced an increase of drilling force for both torque and the thrust force as shown in Fig. 10.

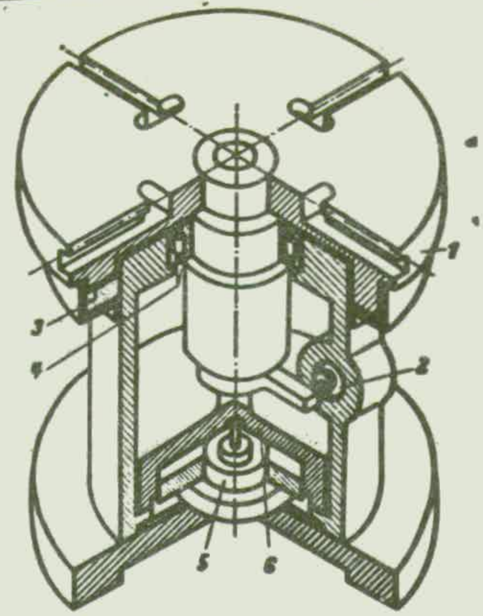


FIG. 1. Dynamometer

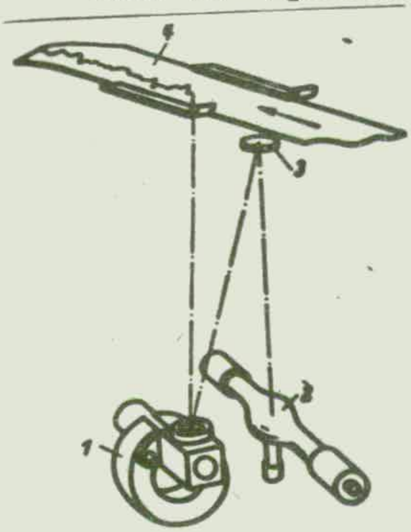
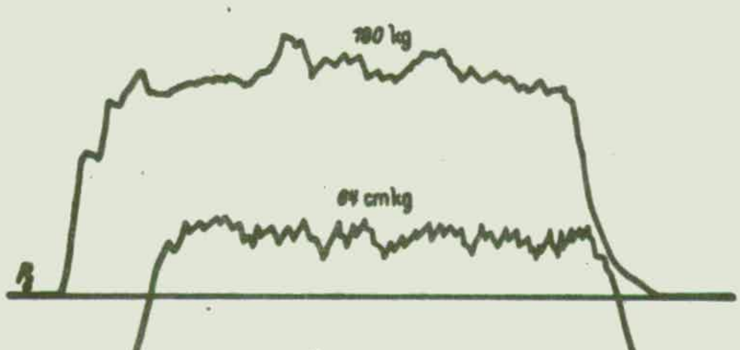


FIG. 2. Light-point recorder



P_z : THRUST
M_d : TORQUE

FIG. 3. Cutting force diagram
from a filled workpiece

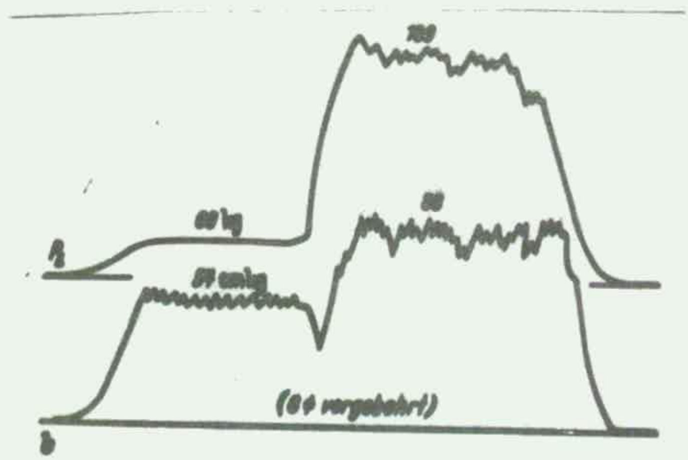


FIG. 4. Cutting force diagram from predrilled workpiece - 6 mm deep

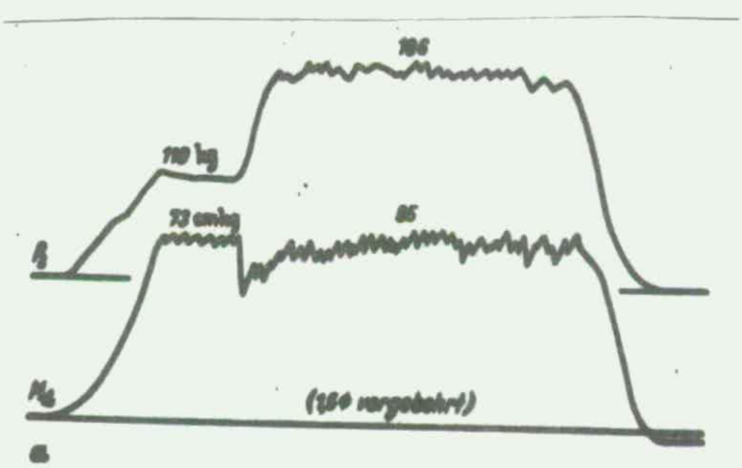


FIG. 5. Cutting force diagram from predrilled workpiece - 10 mm deep

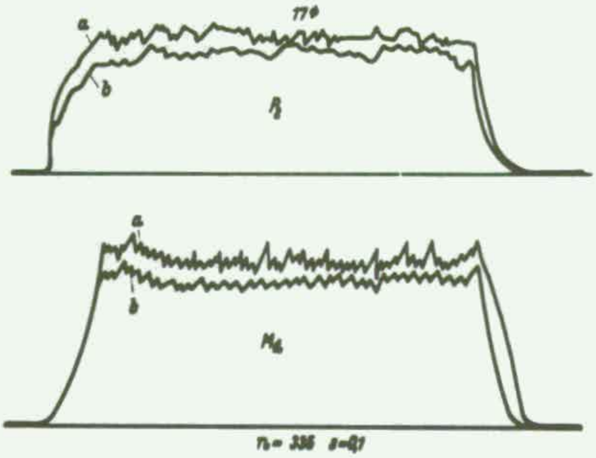


FIG. 6. Drilling force diagram with regular (a) and chip breaker (b)

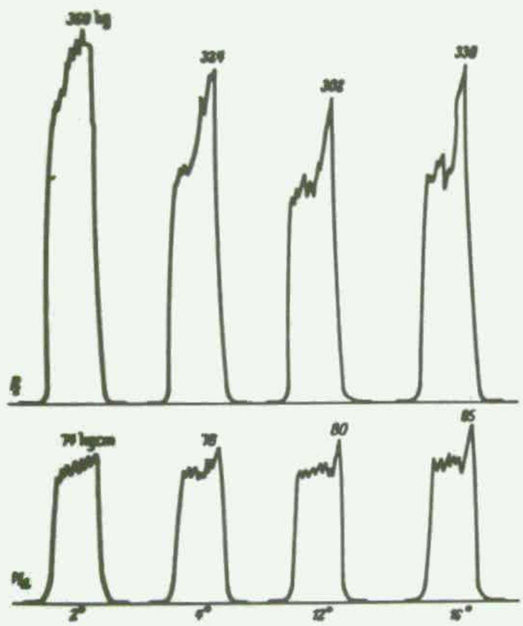


FIG. 7. Effect of lip clearance angle

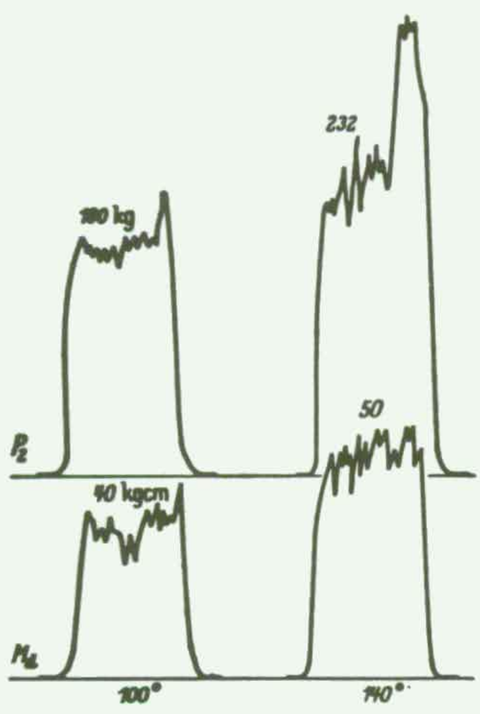


FIG. 8. Effect of point angle

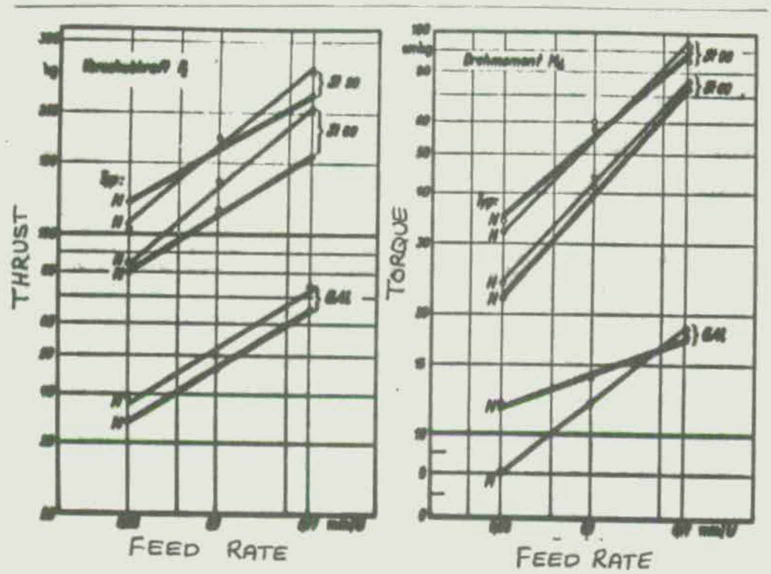


FIG. 9. Exponent for the feed rate

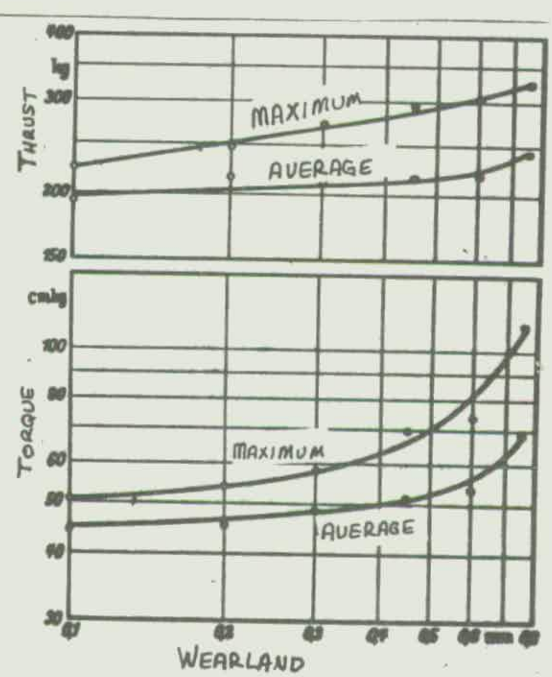


FIG. 10. Torque and thrust
by increased drill wear

1. SHAW, M. C. and OXFORD, C. J., JR.

2. ON THE DRILLING OF METALS 2 - THE TORQUE AND THRUST IN DRILLING

3. TRANS. ASME, January 1957, pp. 139-148

4. In evaluating the total torque and thrust on a drill, three components were considered. The components are: 1) the values due to the cutting edge; 2) the values due to cutting at the chisel edge; 3) the values due to the extrusion process at the chisel edge.

   The authors performed a dimensional analysis on a drill when determining the torque and arrived at the relationship

$$\frac{M}{d^3 H_B} = \left[\frac{f}{d}, \frac{c}{d}, \frac{s}{d}\right]$$

   The variables are feed (f), drill diameter (d), chisel edge length (c), material hardness (H_B) and mean spacing of material imperfections (s).

   The final relationship was arrived at by considering the energy per unit volume associated with the drill lips and the chisel edge. This leads to the torque being given by

$$\frac{M}{d^3 H_B} = K_1 \frac{f^{0.8}}{d^{1.2}} \left[\frac{1 - \left(\frac{c}{d}\right)^2}{\left(1 + \frac{c}{d}\right)^{0.2}} + K_2\left(\frac{c}{d}\right)^{1.8}\right]$$

   The thrust on the drill was analyzed in a similar manner except that there were three components to analyze, the thrust due to cutting at the lips and chisel edge and the thrust due to the extrusion process at the chisel edge.

   Dimensional analysis yielded $\frac{T}{d^2 H_B} = \left(\frac{f}{d}, \frac{c}{d}, \frac{s}{d}\right)$ with the same variables as in the torque analysis. This yielded the following formula for thrust

$$\frac{T}{d^2 H_B} = K_3 \frac{f^{0.8}}{d^{1.2}} \left[\frac{1 - \frac{c}{d}}{\left(1 + \frac{c}{d}\right)^{0.2}} + K_4 \left(\frac{c}{d}\right)^{0.8}\right] + K_5 \left(\frac{c}{d}\right)^2$$

A series of experiments were run to check the theoretically derived equations.

The equation for torque can be reduced to

$$M = K_6\ f^{0.8}\ d^{1.8}$$

if the c/d ratio is held constant. When the values of torque obtained in the experiments are plotted against feed and diameter, Fig. 1, the slopes of the lines are 0.8 for feed and 1.8 for diameter (Fig. 1).

The thrust data were compared with the derived equation by plotting T/d^2H_P versus $f^{0.8}/d^{1.2}$. This yielded a straight line (Fig. 2) indicating the correct combination of variables.

By rearranging the torque and thrust equations, it was determined that with a standard drill ($c/d \cong 0.18$) the chisel edge contributed about 14% of the total torque and about 51% of the thrust. When the web thickness is doubled ($c/d \cong 0.36$) the chisel edge accounts for 38% of the total torque and about 77% of the thrust.

A variation of the helix angle showed a small effect on torque and thrust with both decreasing slightly with increased helix angle (Fig. 3).

For standard drills of c/d = 0.18, the torque and thrust equations can be reduced to

$$M = 0.0087\ H_B\ f^{0.8}\ d^{1.8}$$

$$T = K_1\ \ H_B\ f^{0.63}\ d$$

The influence of feed rate on torque is shown in Fig. 4 for different metals.

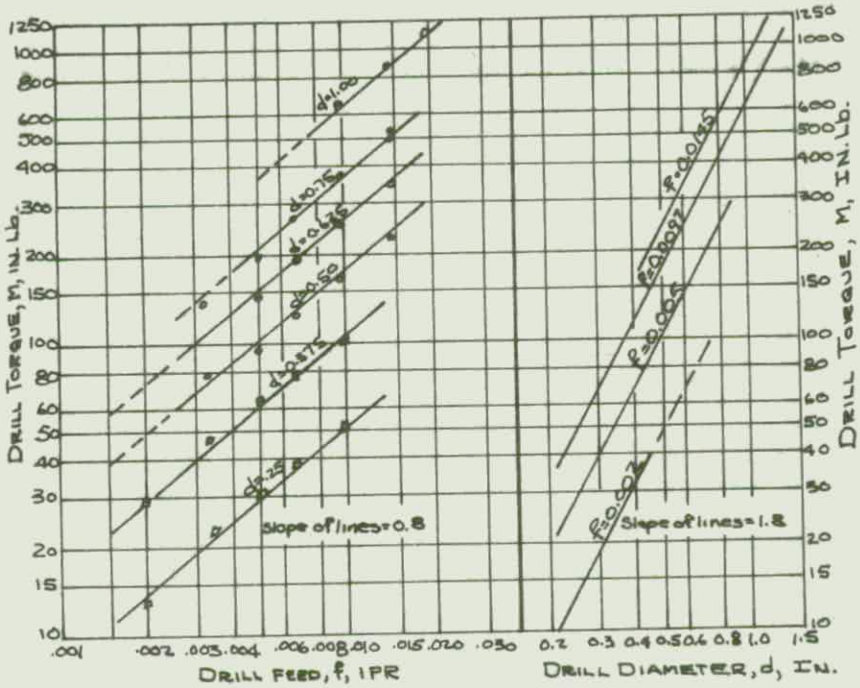


FIG. 1. Relationship of torque to feed rate and diameter

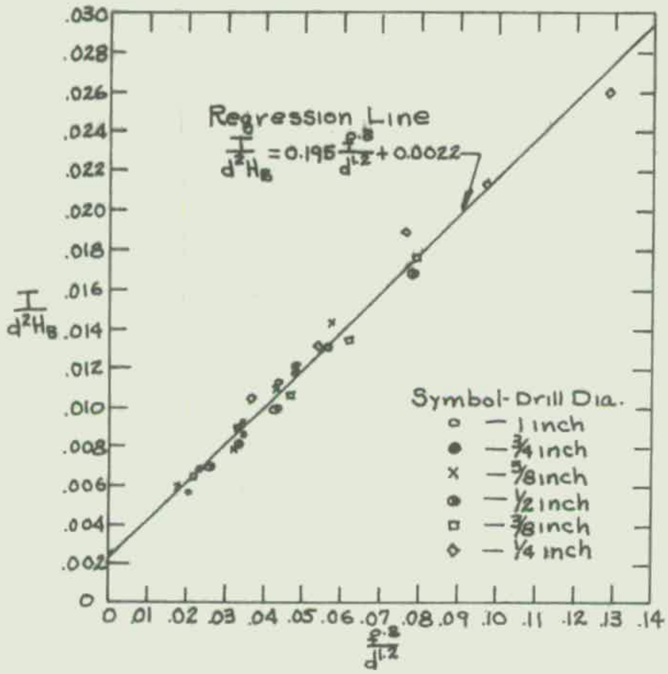


FIG. 2. Plot of T/d^2H_B versus $f^{0.8}/d^{1.2}$

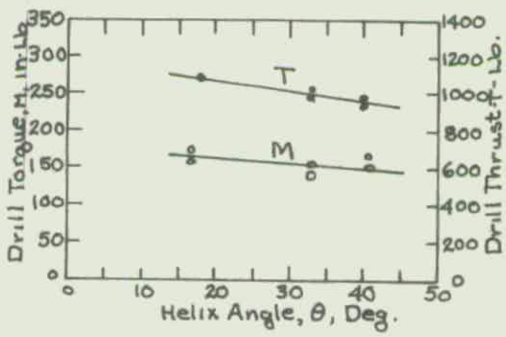


FIG. 3. Effect of helix angle on torque and thrust

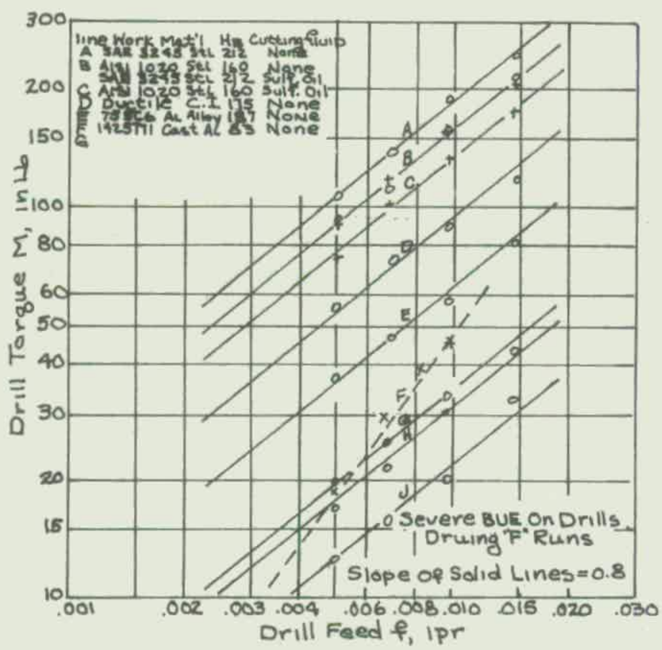


FIG. 4. Influence of feed rate on torque

1. OXFORD, C. J., Jr.

2. DRILLING TECHNOLOGY

3. ASTE TECHNICAL PAPER NO. 59, 1958, Vol. 58

4. Author states that the cutting action of the lips is similar to other machining processes and that the cutting action under the chisel edge is much more complex. This is described as both cutting and extruding.

   The torque and thrust for drilling a chromium-nickel steel of about 200 Bhn were determined to be:

   $M = 25{,}200\ f^{0.8}\ d^{1.8}$ (torque)
   $T = 57{,}500\ f^{0.8}\ d^{0.8} + 625\ d^{2}$ (thrust)

   This applies for a chisel edge length to drill diameter ratio of about 0.18.

   On conducting tests in his laboratory, the author obtained a value of 0.35 to 0.50 for the exponent in Taylor's tool life equation $VN^{n} = C$.

   It is shown that drill length has an effect on drill life with shorter drills producing more holes per grind than long ones.

   As web thickness increases, the required thrust force also increases. This is alleviated by web thinning. The Spiral Point drill also reduces the thrust as compared to a standard drill.

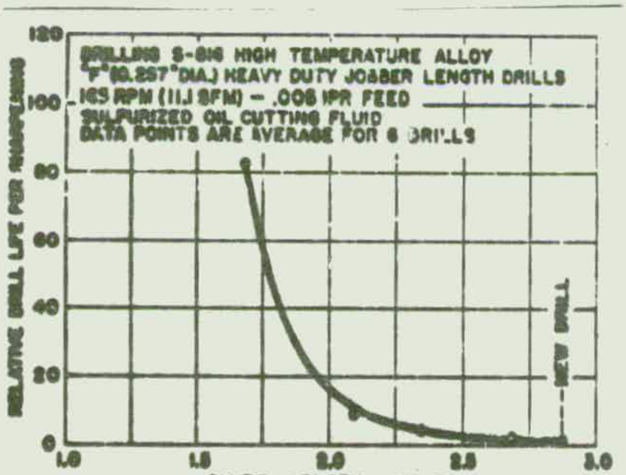


FIG. 1. Relationship of drill length to drill life

1. LISTER, T. S. and KINMAN, M. D.

2. MACHINING OF CORROSION AND HEAT RESISTANT STEELS AND ALLOYS

3. PROC. OF THE CONFERENCE ON TECHNOLOGY OF ENGINEERING MANUFACTURING, London, March 25-27, 1958, No. 43, pp. 342-349

4. The drill geometry shown in Fig. 1 is recommended for drilling high temperature steels and Nimonics. Rigidity is obtained by making the flutes short, using a heavy web and a high helix angle. The negative rake of the chisel edge is made positive by the point thinning. The drill must be withdrawn to clear the chips after drilling to a depth of approximately two drill diameters.

   General recommendations for drill designs for four different classifications of materials are given in Table 1.

   Drilling tests were conducted on the steels listed in Table 2 with 1/8 in. diameter drills.

   When drilling at a speed of 52 ft/min and a penetration rate of 4 in/min, a drill life of 50 to 200 holes was obtained for steels 1, 2 and 3 while the tests were discontinued at 1000 holes for steel 4.

   Tests were conducted on the four steels with a constant feed rate of 0.003 ipr while the speed was varied from 1000 to 4000 RPM. The free machining grade produced lower forces, Fig. 2. The same was true, Fig. 3, when the feed rate was varied and the speed held constant (1000 RPM).

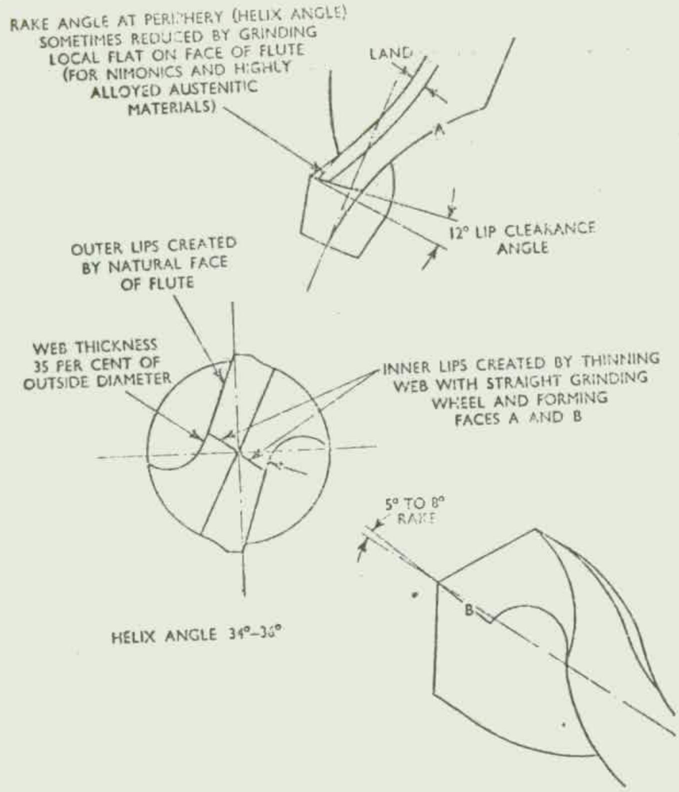


FIG. 1. Recommended drill geometry

TABLE 1. High speed steel

Type	Percentage composition	Characteristics	Examples of uses
18/4/1	0·72/0·78 carbon, 18 tungsten, 4 chromium, 1 vanadium	Good wear resistance and hot hardness combined with toughness	Drills, taps, broaches
10 per cent cobalt	0·82 carbon, 20 tungsten, 5 chromium, 10 cobalt	Higher hot hardness with some loss of toughness	Turning with heavy continuous cuts
High vanadium	1·20 carbon, 14 tungsten, 4·5 chromium, 4 vanadium	High wear resistance. Resists abrasive action of high-temperature steels	Milling cutters and turning tools for the more abrasive materials. Form tools and cut-off blades
High vanadium cobalt	1·50 carbon, 12·5 tungsten, 4·5 chromium, 5 vanadium, 5 cobalt	Maximum wear resistance combined with maximum hot hardness	

TABLE 2. Materials used for this test

Material	Nominal percentage analysis
(1) 18/8 type . . .	0·12 carbon, 17·0 chromium, 10·5 nickel
(2) 18/8+molybdenum type	0·12 carbon, 18·5 chromium, 9·5 nickel, 2·75 molybdenum
(3) High-manganese type .	0·12 carbon, 8·0 manganese, 5·0 nickel, 18·0 chromium
(4) Free-machining 18/8 .	As for (1) plus 0·30 sulphur, 0·30 molybdenum, 2·0 manganese

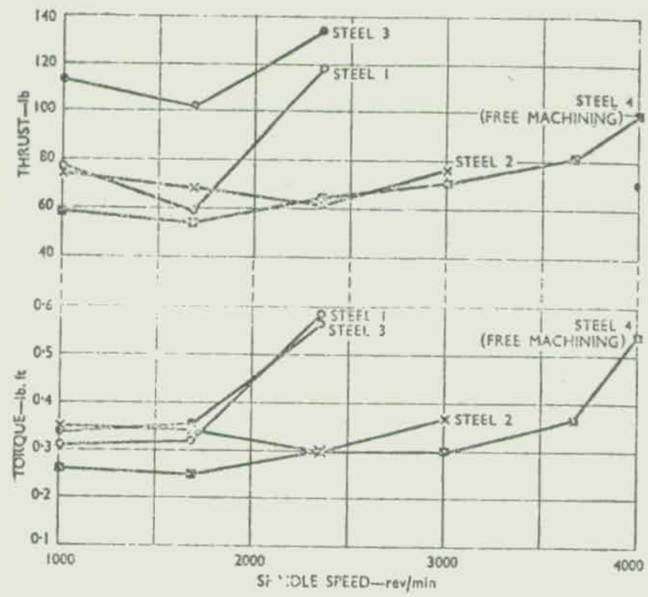


FIG. 2. Torque and thrust measurements with varying speed

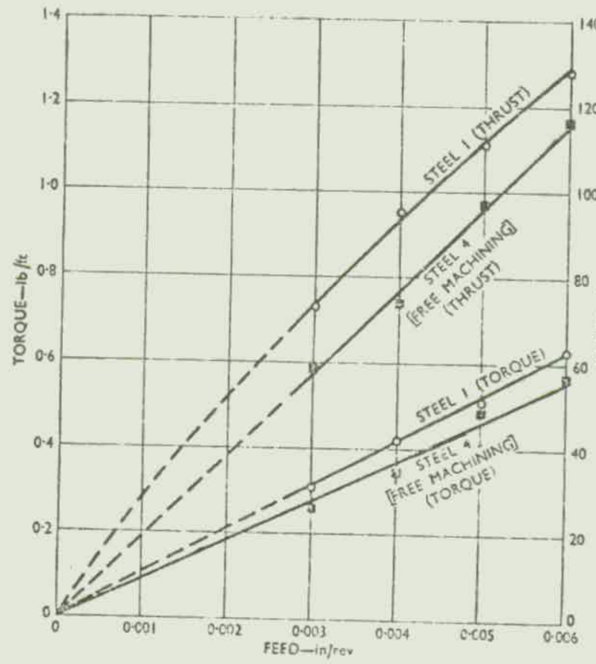


FIG. 3. Torque and thrust readings with constant speed and varying feed

1. COWIE, R. J. AND J. O. M. PEGLER

2. SOME FACTORS AFFECTING THE PERFORMANCE OF DRILLS AND TAPS

3. THE INSTITUTION OF MECHANICAL ENGINEERS, PROCEEDINGS OF THE CONFERENCE ON TECHNOLOGY OF ENGINEERING MANUFACTURE, March, 1958, pp. 463-472

4. Tests were conducted to determine the effect of varying the point geometry on drill performance. The effect of varying the point angle on drill life was found for three different steels, EN3A, EN30B and EN10. The results, shown in Fig. 1, indicate that there is a large difference in drill life for the various point angles for each material. It is also indicated that what is an optimum condition for one material does not necessarily produce an optimum performance for another material.

The tests were conducted by starting with the maximum point angle shown for each material and reducing it. As the point angle is reduced the undeformed chip thickness is also reduced. When associated with the fact that when turning steel a reduction in chip thickness produces an improved tool performance it was proposed that the point angle on drills be reduced to the stage where structure of the drill point impose a limitation.

Tests were also conducted to determine the effect of the relief angle on the drill performance and results similar to those obtained for the point angle were obtained. An optimum condition for each material was found with the drill performance decreasing as the angle was varied from this optimum. This is shown in Fig. 2.

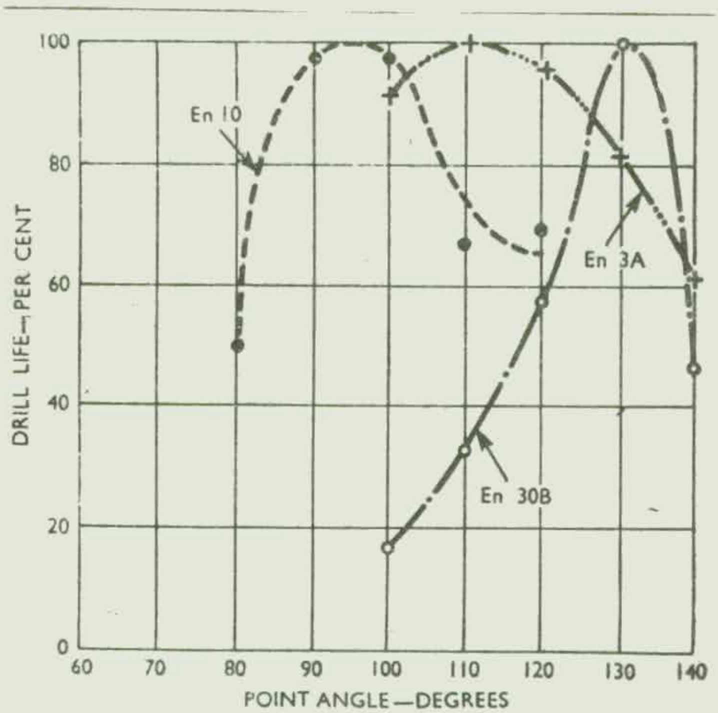


FIG. 1. Effect of point angle on drill life

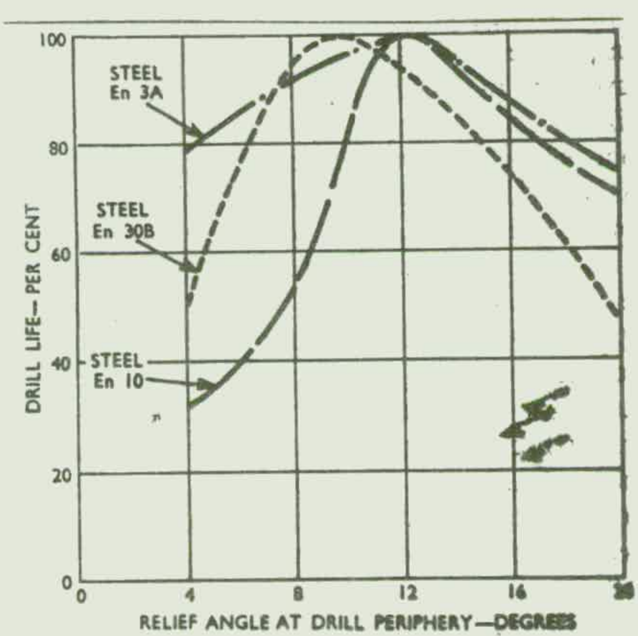


FIG. 2. Effect of relief angle on drill life

1. HOLLIS, W. S.

2. THE MACHINING OF TITANIUM ALLOYS

3. THE INSTITUTION OF MECHANICAL ENGINEERS, PROCEEDINGS OF THE CONFERENCE ON TECHNOLOGY OF ENGINEERING MANUFACTURERS, March, 1958, pp. 350-364

4. When drilling titanium alloys rigidity is important in order to eliminate drill chatter which will cause work hardening. The work hardening causes variations in the cutting torque and subsequent drill breakage.

It was found that a point angle of 115-120 degree gave the best performance. A helix angle of 38 degrees produced a good combination of drill forces and drill life. The variation of torque, thrust and drill life with helix angle is shown in Table 1 and Fig. 1.

In order to reduce galling, it is important to have an accurate drill point. The point geometry that was tested on various alloys is shown in Fig. 2.

Tests were conducted on cutting fluids to determine cooling characteristics and the prevention of chip weldment. Soluble oils were found to perform satisfactorily in the cutting speed range of 20-40 fpm. A comparison of various cutting fluids is shown in Fig. 3.

Design	Helix, deg	Torque, lb/in.	Thrust, lb.	Life, in.
Nimonic . .	12	35	450	1·0
Standard . .	26	30	430	3·0
Standard . .	38	32	260	0·8
Nimonic . .	38	24	410	12·0
Standard . .	12	50	335	0·4

Drill diameter $\frac{3}{16}$ in. Speed 15·6 ft²/min.
Feed 0·006 in./rev. Material Ti–6Al–1Fe.

TABLE 1

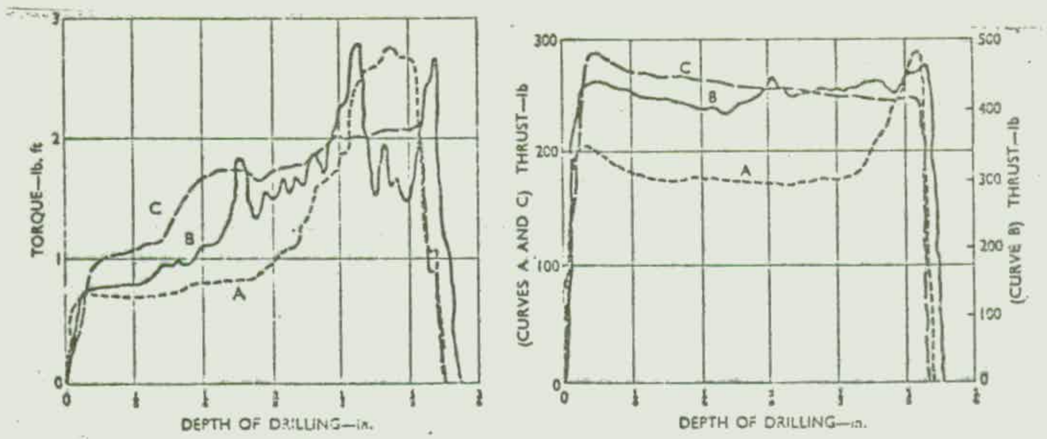


FIG. 1

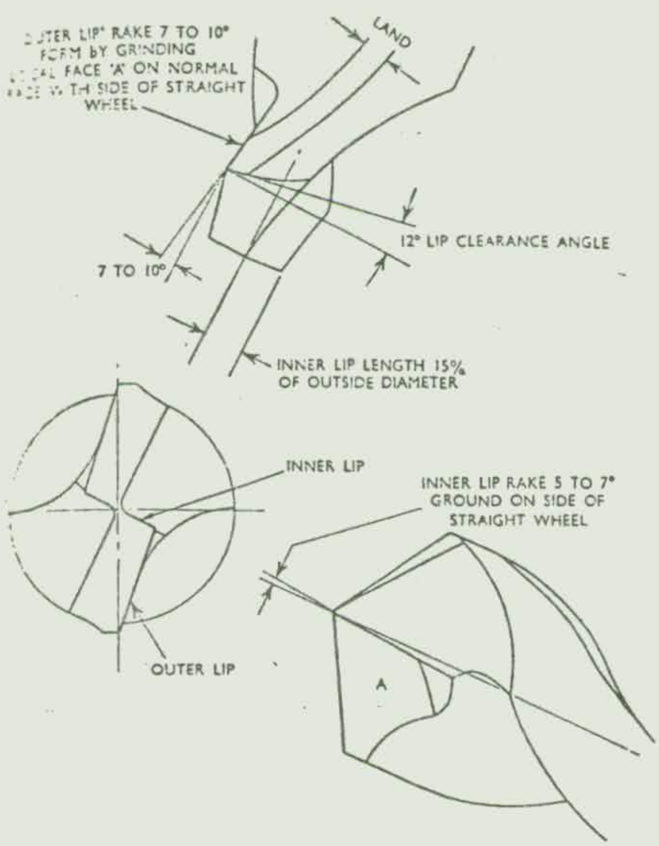


FIG. 2

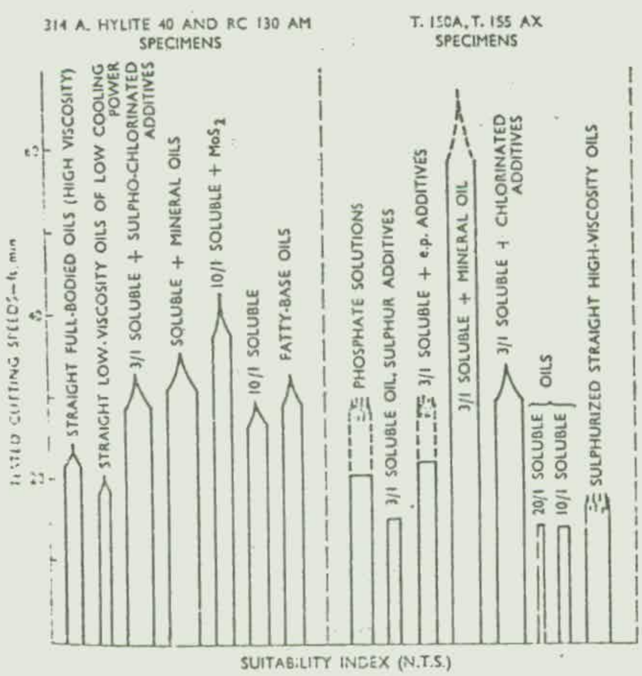


FIG. 3

1. ERNST, H. and HAGGERTY, W. A.

2. THE SPIRAL POINT DRILL - A NEW CONCEPT IN DRILL POINT GEOMETRY

3. TRANS. ASME, 1958, July, pp. 1059-1072

4. Ernst and Haggerty point out that the cutting conditions in the region of the chisel edge are bad due to a high negative rake angle and a lack of space for the egress of the chip. The drill also has no self-centering action when it enters the workpiece due to the shape of the chisel edge and the surface it generates since both are flat planes perpendicular to the drill axis. If one end of the chisel edge is higher than the other the drill will have a tendency to "walk" to one side or the other.

   The method used to generate the spiral point is shown in Fig. 1.

   The difference in chip formation between the spiral point and chisel edge drill is observed when the photomicrographs of the two points are compared for corresponding sections. This difference is very pronounced near the drill axis becoming less apparent on the main cutting lips. This difference is shown in Figs. 2 and 3.

   The difference in normal rake and face rake angles versus radial distance for the spiral point and chisel edge drill can be observed in Figs. 4 and 5.

   Due to the nature of the spiral point geometry, it terminates at the drill axis in a sharp point. This point eliminates the tendency of the drill to "walk" to one side or the other as the drill enters the workpiece. Thus the spiral point drill is said to produce straighter, rounder, smoother and closer to size holes than chisel point drills.

   Tests were run on 5 different steels to compare thrust and torque for spiral point and chisel point drills. The measured values of torque for the spiral point drill was approximately 4 percent less than the values obtained for chisel point drills. The measured thrust values for the spiral point were 15 to 34 percent less than the values obtained for the conventional chisel point drill.

   Utilizing a rapid increase in thrust force as a criterion for drill life, the spiral point drills were reported to outdrill the chisel points drills approximately 2 to 1.

By modifying the "point angle" of the spiral point drill so that the "point angle" is 180 deg. at the outer edges of the drill and still maintains the spiral point at the center, a drill was found that is effective in drilling sheet metal. This modification is said to produce a rounder hole that is burr-free on the underside of the hole.

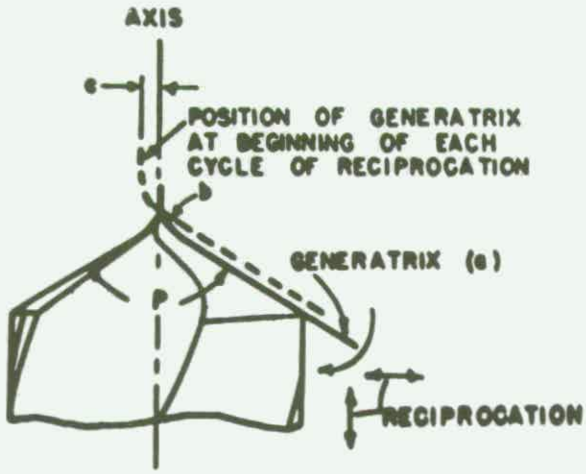


FIG. 1. Generation of spiral point

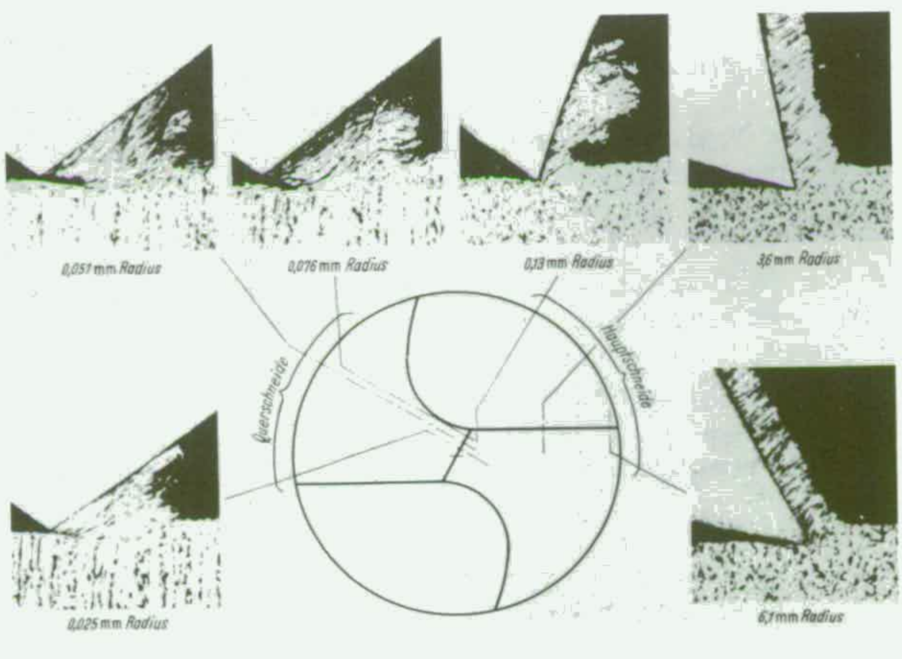


FIG. 2. Photomicrographs of chip formation under chisel edge and along cutting edge

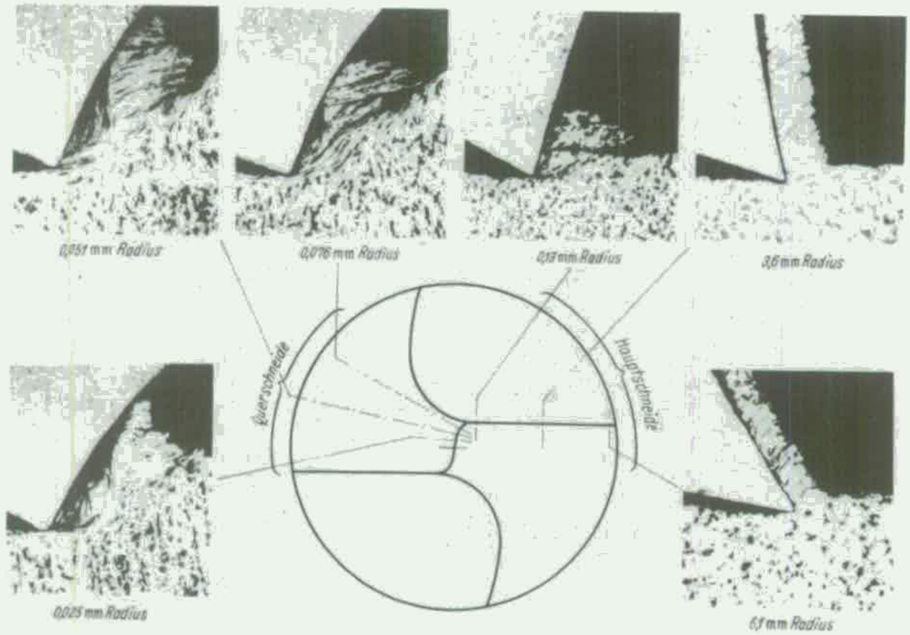


FIG. 3. Photomicrograph of chip formation under the point of a spiral point drill and along the cutting edges

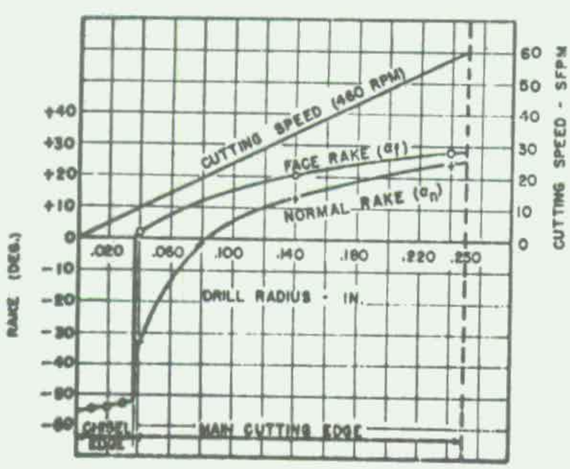


FIG. 4. Values of normal rake, face rake and cutting speed for a ½ in. diam. chisel point drill (α_n calculated at zero feed rate)

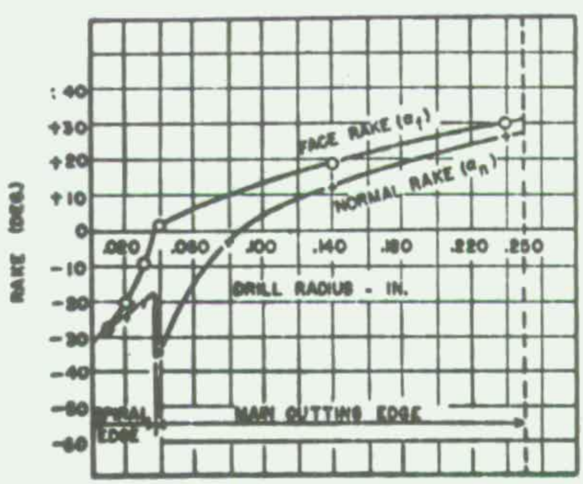


FIG. 5. Values of normal rake, face rake and cutting speed for a ½ in. diam. spiral point drill (α_n calculated at zero feed rate)

1. OXFORD, C. J., JR.

2. STANDARD OR SPECIAL DRILLS .... PROPER APPLICATION REDUCES COST

3. THE TOOL ENGINEER, August, 1959, pp. 50-54

4. Standard drills are generally chosen over special drills due to their availability from stock whereas special drills are used when a standard drill cannot do the job and where costs can be reduced.

   As is shown in Fig. 1 as the cutting speed or feed rate are increased, tool life is shortened. Usually, the cutting speed shows a larger effect in reducing tool life than feed rate. For drills this means selecting highest feed rate with moderate cutting speeds.

   Drill life, in holes per grind, varies inversely with a power of feed rate and cutting speed. The speed exponent is between two and three and the feed exponent is around 1.5.

   The effect of tool life on machining costs and optimum cutting speed is shown in Fig. 2.

   To improve hole quality and reduce drill breakage when drilling sheet metal short flute drills are recommended.

   The choice between subland and step drills depends on the length of the step. If the step is long there is not much difference in drill life although for short steps the subland type is the best.

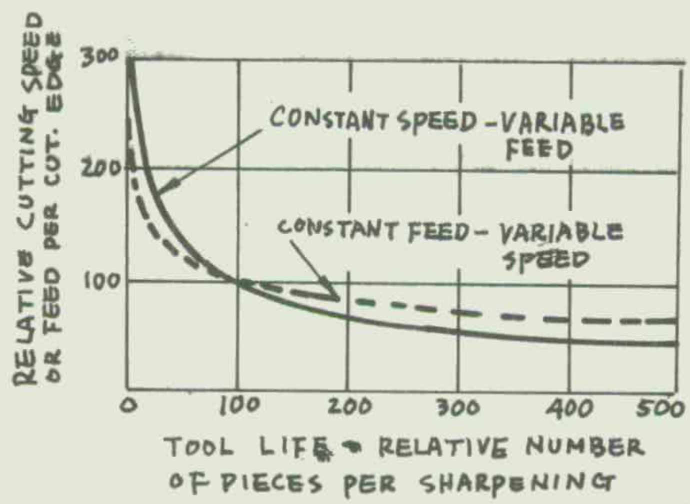


FIG. 1. Effect of changing tool life on the cost per piece produced

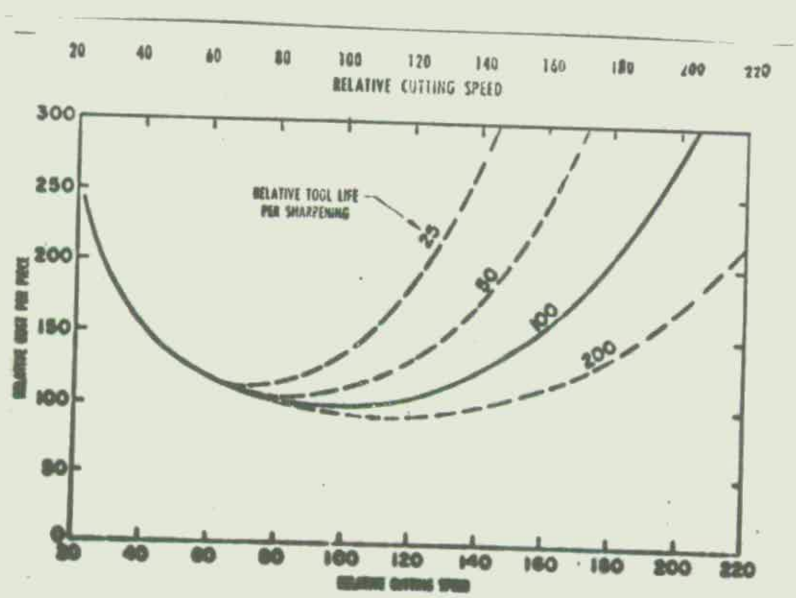


FIG. 2. Cutting speed vs. drill life

1. PAHLITZSCH, G. and SPUR, G.

2. EINRICHTUNGEN ZUM MESSEN DER SCHNITTKRÄFTE BEIM BOHREN (Devices for Measuring Cutting Forces in Drilling)

3. WERKSTATTSTECHNIK, 1959, Vol. 49, No. 6, pp. 302-308

4. An introduction to dynamometry is presented including a discussion of principles, requirements of design. Force components in drilling are discussed and a review of existing drilling dynamometer designs is included.

The authors developed a two-component dynamometer using strain gages (Fig. 1). The dynamometer was constructed in two parts, e.g. one hollow tube for measuring torque, and four rings for measuring thrust. They also designed a one-component dynamometer which was able to measure the radial force with the number of rotations of the drill (Fig. 2).

Modifying the above two types of dynamometers, the authors developed a three-component dynamometer using a unique idea that made it possible to measure thrust, torque and also radial force. The strain gages were fixed to four spokes of a wheel-type workpiece holder. The spokes are stressed by the influence of the cutting forces as indicated in Fig. 3.

An example of a recording of the three force components is introduced in Fig. 4.

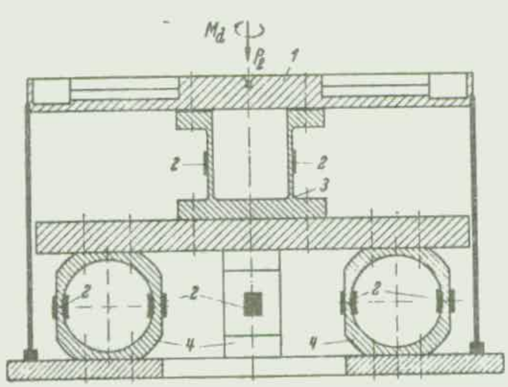


FIG. 1. 2-component dynamometer

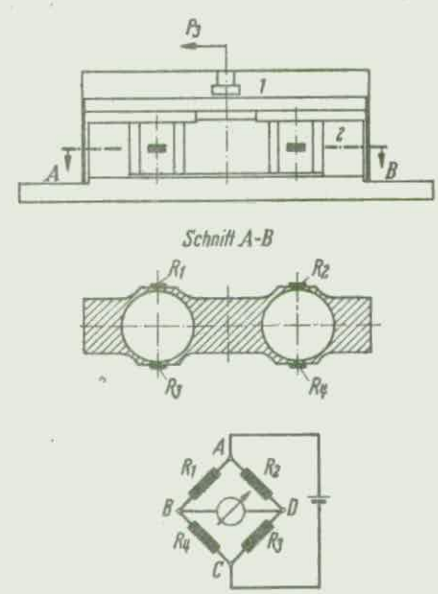


FIG. 2. One component dynamometer for measuring radial force

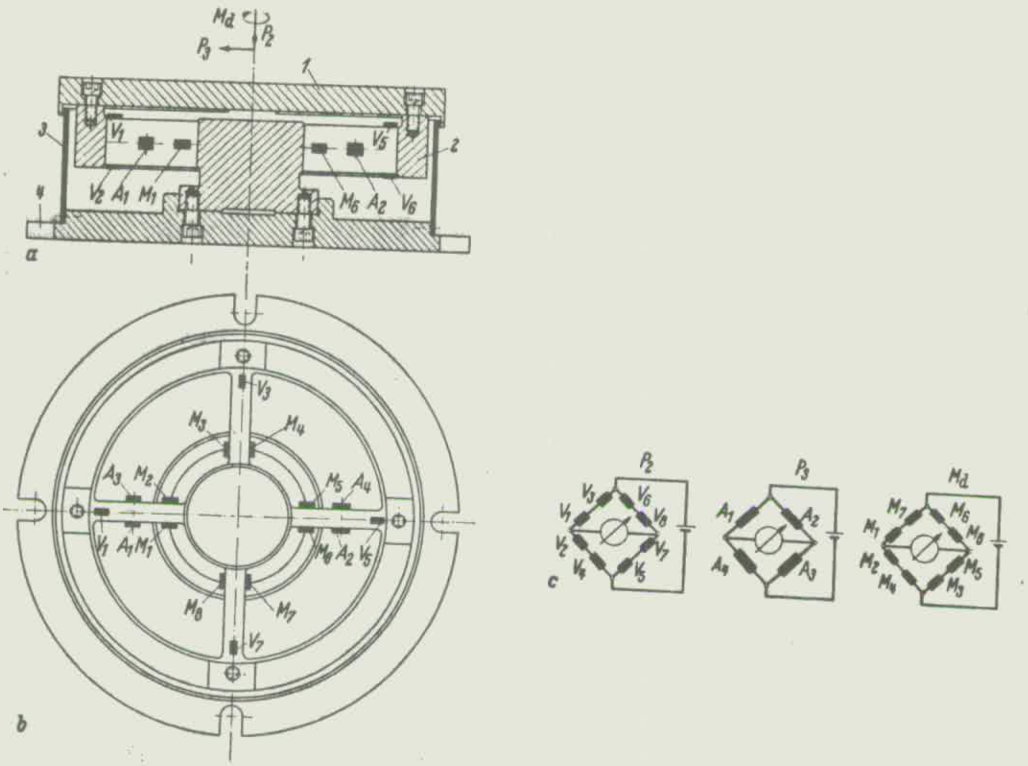


FIG. 3. Three-component dynamometer which is able to measure thrust, torque and radial forces

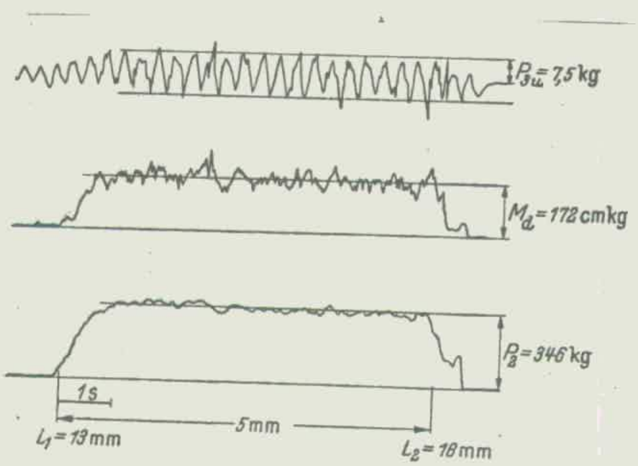


FIG. 4. Examples of recording of three force measurements

1. LOGSDON, B. E.

2. SPADE DRILLS vs. TWIST DRILLS ... TEST RESULTS

3. THE TOOL ENGINEER, January, 1959, pp. 70-71

4. Comparative tests were run on 1-7/8 and 2-5/8 in. diameter spade and twist drills. A flood coolant was used with the twist drills and a pressurized coolant with the spade drills.

   A list of comparative data is shown in Table 1 for tests on one material.

   It is recommended that spade drills not be run at the same speeds and feeds that twist drills are operated at. The spade drills operate best at higher speeds and lower feed rates.

   When the breakage of twist drills is a problem, spade drills should be considered due to their greater rigidity.

Comparative Drilling Tests

Operating Conditions	Spade Drill	Twist Drill
Drill diam (inch)	2⅝	2⅝
Material (SAE No.)	8620	8620
Surface speed (sfm)	97	70.7
Feed (ipr)	0.010	0.0137
Feed rate (inch)	1.41	1.41
Coolant pressure (psi)	30	flow
Output (hp)	8.44	8.44
Thrust load (lb)	4389	5082

TABLE 1

1. ANONYMOUS

2. DRILLING TECHNIQUE

3. TOOL ENGINEERS HANDBOOK, SECOND EDITION, 1959, Published by McGraw-Hill Book Company

4. Drill web thickness has only a minor influence on the torque and horsepower required. Fig. 1 indicates that if the web thickness were doubled, the total torque required would increase less than 25%.

   Drill thrust force is very sensitive to change in drill web thickness. Fig. 1 indicates that doubling the web thickness will increase thrust force by more than 60%.

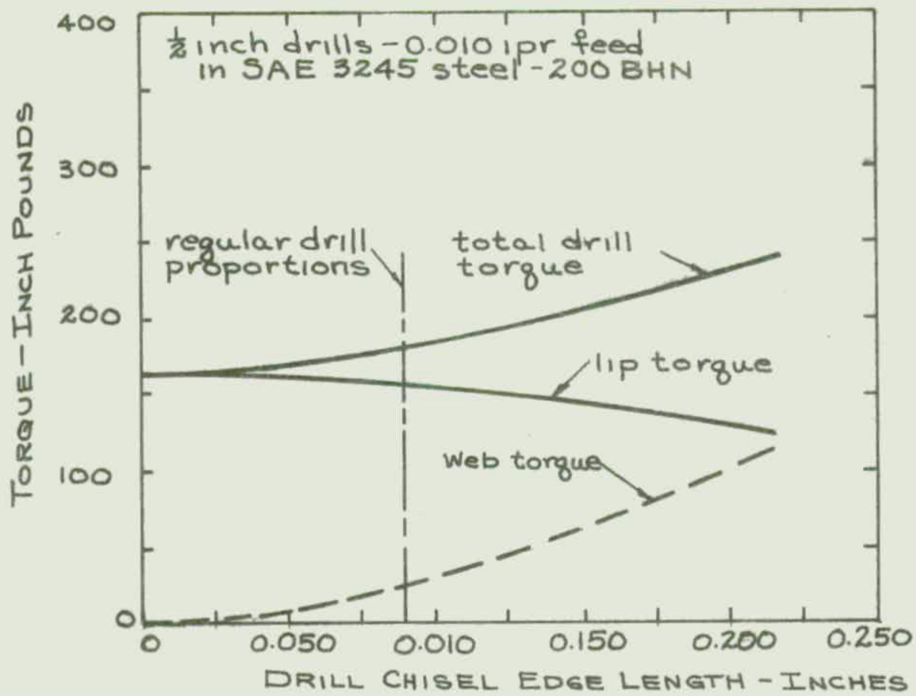


FIG. 1. Torque vs. chisel edge length

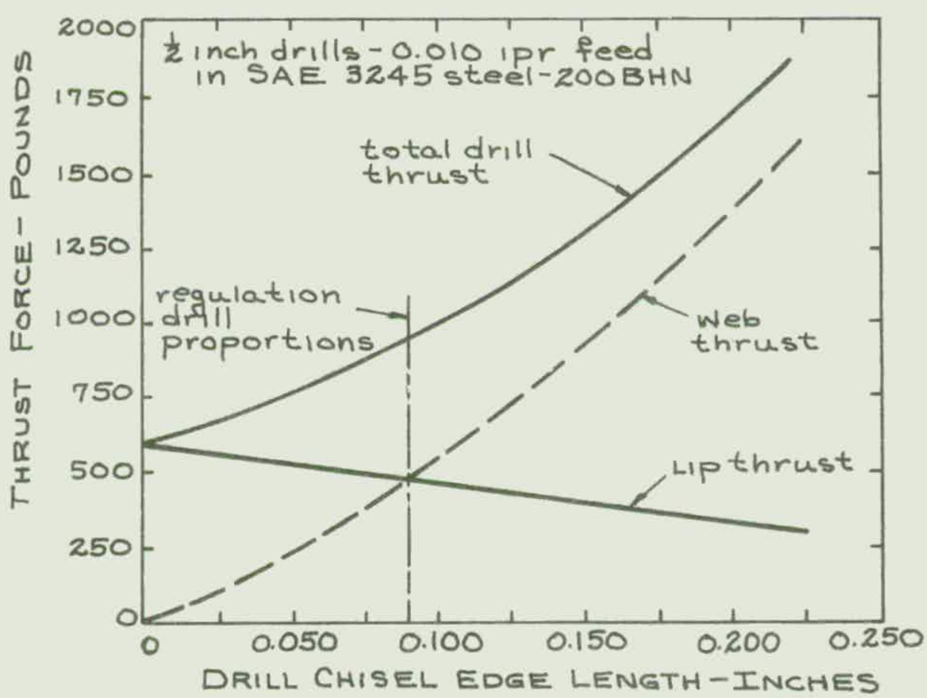


FIG. 2. Thrust vs. chisel edge length

1. AFANAS'EV, V. F.

2. HIGH-SPEED DRILLING IN HIGH-STRENGTH CAST IRON

3. RUSSIAN ENGINEERING JOURNAL, Vol. 40, 1960, No. 10, pp. 48-49

4. The author has derived the following relationship relating tool life T, speed v, feed s, drill diameter D and length of the hole drilled L.

$$v = \frac{C_V D^{0.50}}{T^{0.30}\, s^{0.50}\, L^{0.60}}$$

The constant C_V depends on the hardness of the iron and is given by

H_B	220	240	260	280	300	320	340
C_V	108.6	101.1	94.1	87	72.4	65.1	58

1. HAGGERTY, W. A.

2. THE EFFECT OF DRILL SYMMETRY ON PERFORMANCE

3. ASTME TECHNICAL PAPER NO. 254, Presented at 28th Annual Meeting, 1960, pp. 1-8

4. The effect of lip height difference on hole oversize for both chisel edge and spiral point drills was determined (Fig. 1). The lip height difference varied from 0.000 to 0.006 in. The drills were run at 520 RPM with a feed rate of 0.007 ipr in SAE 4340.

   The relative lip height can be calculated by the following relationship:

$$H = w \tan \beta \left[1 + \frac{\sin \beta \sin \tau}{\sin(90 - \tau - \beta)} \right]$$

   where

   H = relative lip height (in.)

   w = web eccentricity

   β = relief angle

   τ = helix angle

   The relative lip height at various radii on three spiral point drills with differing web eccentricities is shown in Fig. 2.

   The effect of web eccentricity, varying from 0.000 to 0.020, on hole oversize for chisel edge and spiral point drills is given in Fig. 3. Web eccentricity also affects drill life (Fig. 4).

NOTE: This same article "Drill Symmetry - Effects on Hole Production" is available from THE TOOL ENGINEER, June 15, 1960, pp. 83-86.

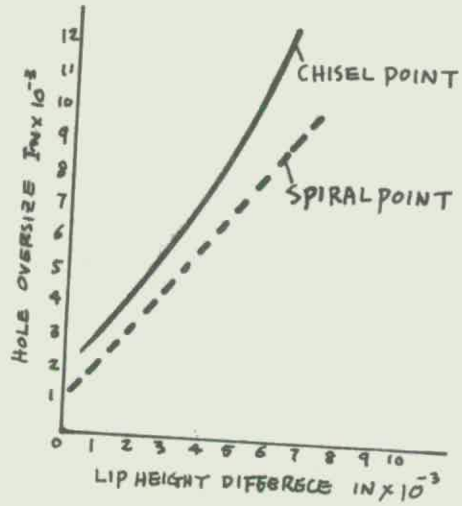


FIG. 1. Hole oversize for a 0.500-in. dia. drill as affected by lip-height difference

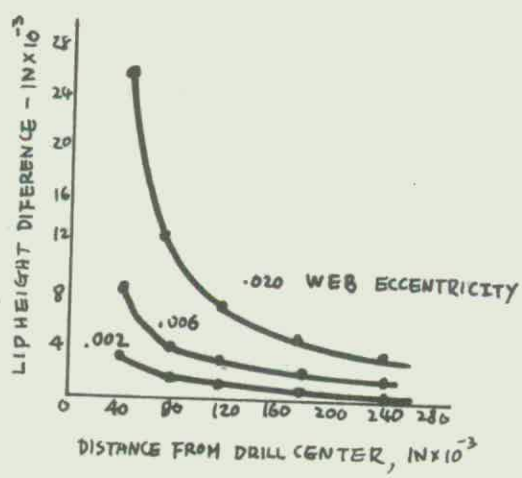


FIG. 2. Difference in relative lip height at various radii as affected by web eccentricity

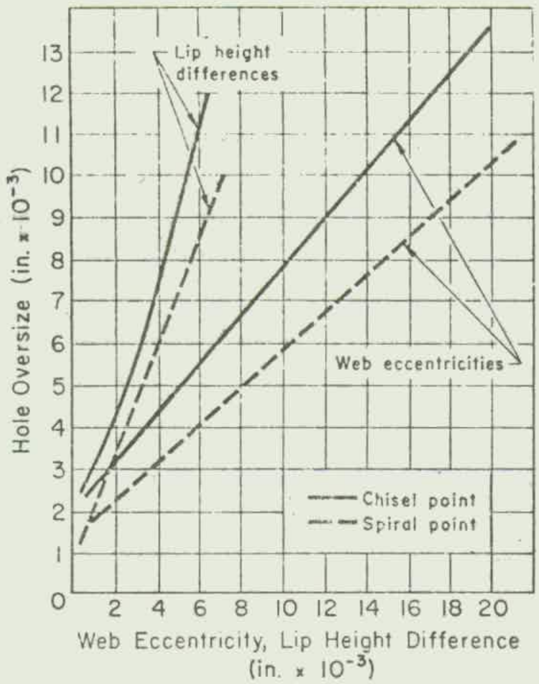


FIG. 3. Hole oversize as a function of web eccentricity

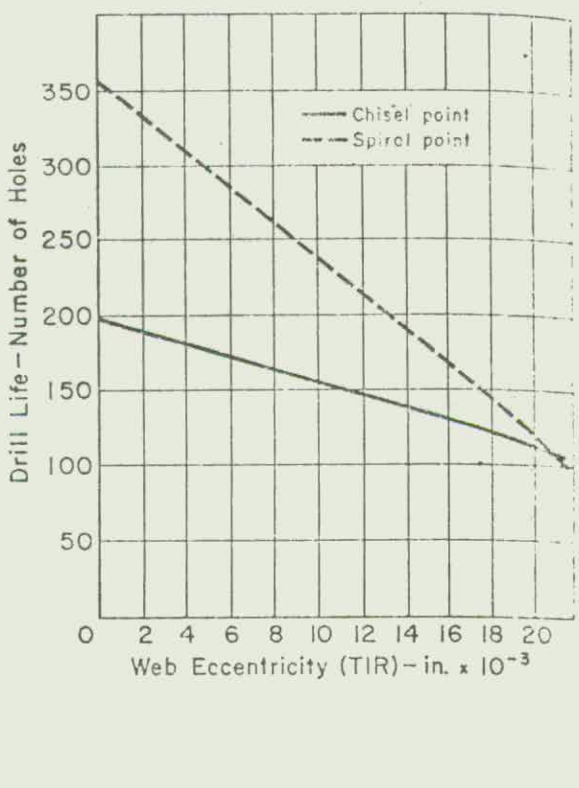


FIG. 4. Influence of web eccentricity on drill life

1. ZAGAR, FRANK

2. DRILLING HOLES TO SIZE ... IN ONE OPERATION

3. THE TOOL AND MANUFACTURING ENGINEER, Dec. 1960, pp. 65-66

4. In order to drill holes to size with close tolerances, and eliminate a reaming operation, step drills are recommended.

   When the pilot portion of the drill enters the workpiece it may make a hole that is larger than its own diameter although when the body portion of the drill begins to cut it centers the pilot portion and drills the hole to size. This is illustrated in Fig. 1.

   The step and body portion of the drill should be concentric with each other. The pilot diameter should be three-fourths as large as the body diameter and approximately two-thirds of the body diameter in length.

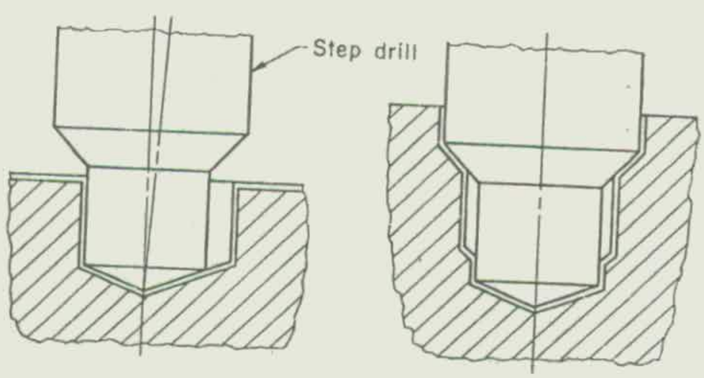


FIG. 1. (right) When pilot enters the hole (left) it may drill oversize 10 percent of the time. When the drill body enters the hole, however, it centers the pilot, producing a finished hole that is within tolerances.

1. MONAHAN, F. A.

2. SUB-ZERO MACHINING

3. AMERICAN MACHINIST, 1960, Vol. 104, No. 10, pp. 109-124

4. Three different methods of cooling were tried in these tests:

   1. Surround the work area with CO_2 mist at -109F.
   2. Use dry-iced coolant to flood the work area at -76F.
   3. Deepfreeze the part itself.

   When drilling L-605, a cobalt base, high-temperature, oxidation and carburization resistant alloy a flood coolant of refrigerated solvolene produced the best tool life at 48 fpm, Fig. 1, although a room temperature coolant gave a greater tool life at 30 fpm. The solvolene coolant also produced the greatest torque and the least thrust as shown in Fig. 2.

   When drilling R-235, a nickel-base, preciptiation-hardening alloy, at 22 fpm, the flood coolant again produced the best tool life, Fig. 3, and metal removal rate. The solvolene coolant produced lower drilling forces than the CO_2 mist although a sulphurized oil and kerosene produced lower forces yet at a speed of 14 fpm, Fig. 4.

   Drilling a molybdenum-titanium (Mo-0.5% Ti) alloy CO_2 mist and solvolene flood coolant produced better tool life, Fig. 5, than room temperature coolants at 66 fpm. The room temperature coolant produced lower torque and thrust forces than the CO_2 mist or the flood coolant as shown in Fig. 6.

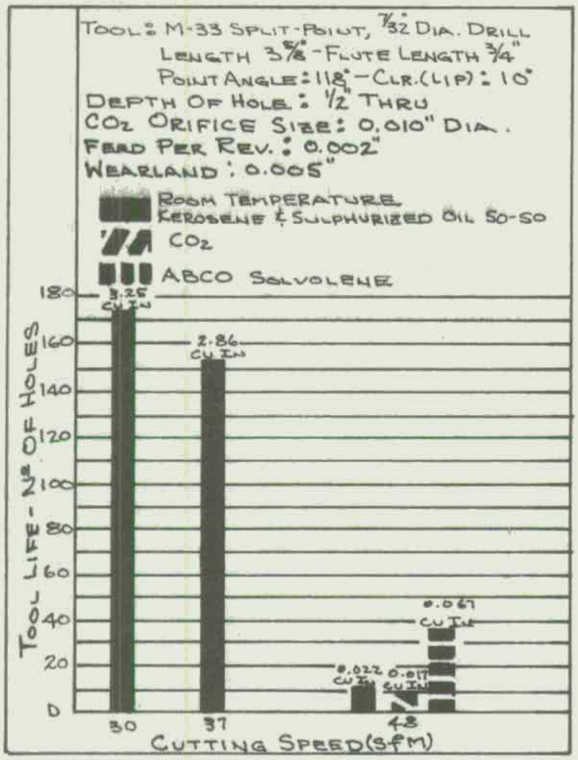


FIG. 1. Influence of coolant on drill life when drilling L-605

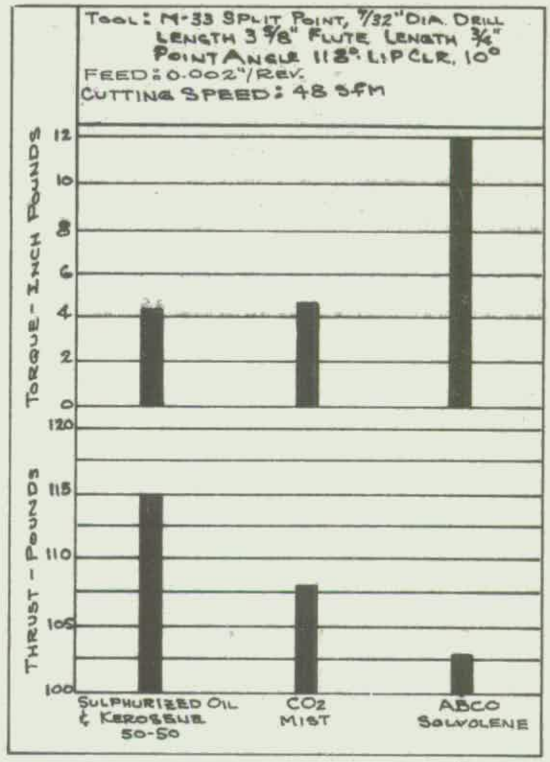


FIG. 2. Influence of coolant on torque and thrust when drilling L-605

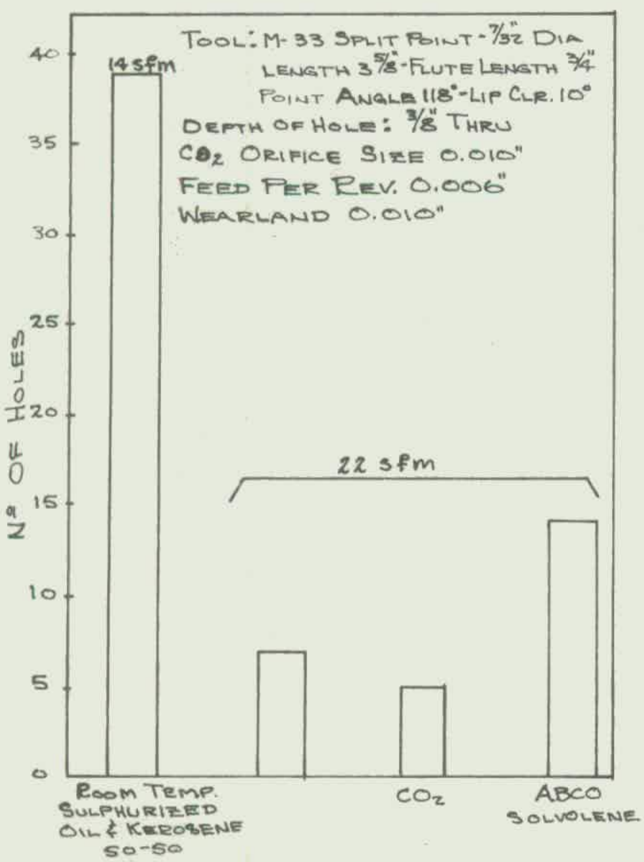


FIG. 3. Influence of coolant on drill life when drilling R-235

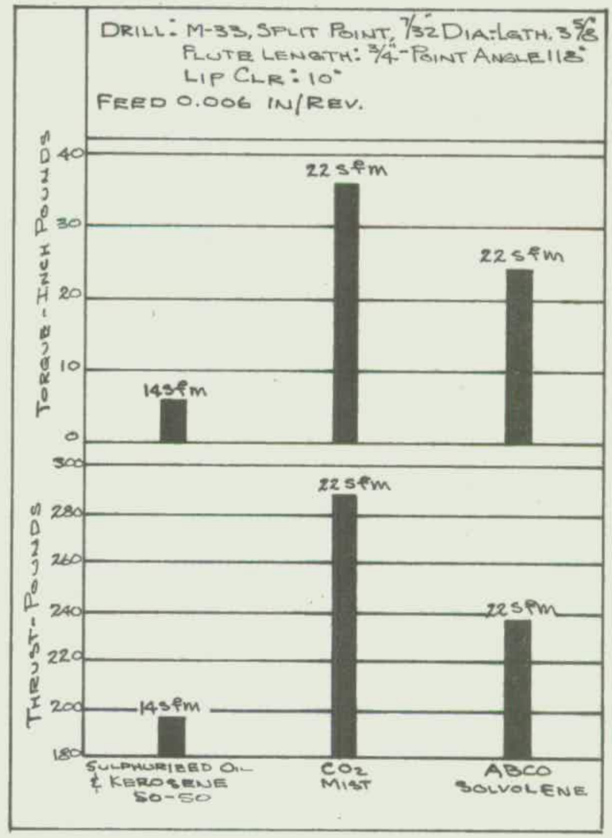


FIG. 4. Influence of coolant on torque and thrust when drilling R-235

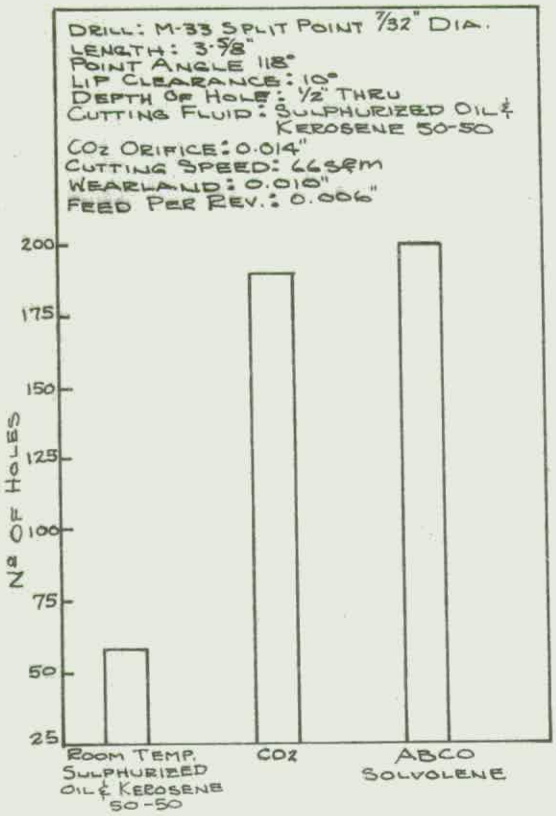


FIG. 5. Effect of coolant on drill life when drilling a molybdenum-titanium alloy

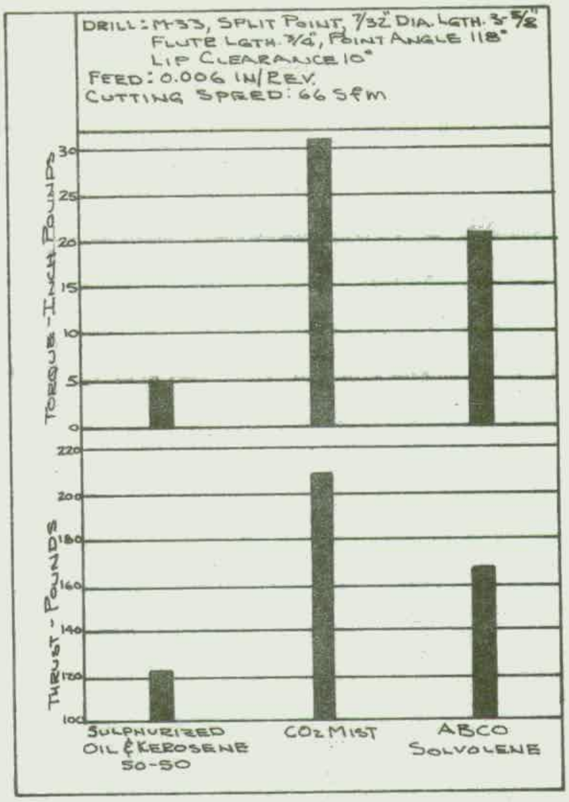


FIG. 6. Effect of coolant on torque and thrust when drilling a molybdenum-titanium alloy

1. HALL, H.L., GREHN, W. and WUNSCH, A.

2. BRINGT DER SPIRALBOHRER-SONDERANSCHLIFF WIRTSCHAFTLICHE VORTEILE BEI DER GRAUGUSS-BEARBEITUNG? (Are there economic advantages in cutting cast iron with drills having specially ground points?)

3. WERKSTATTSTECHNIK, 1960, Vol. 50, No. 6, pp. 305-309

4. Tool life for cutting cast iron with specially ground twist drills (Figs. 1, 2 and 3) was improved. For drilling of pre-machined surfaces the improvement was 25 to 30% and for as-cast surfaces up to 100%. For example, Fig. 4 shows arithmetic mean wear curves for normal grind as well as special grind drills entering and leaving unworked surfaces. An improvement in tool life of about 100% is indicated.

   Maintenance costs of drills with specially ground points tend to limit their economy. Plots of tool cost per drilled hole versus ratio of useful twist length-to-overall twist length show poor economy for drilling of pre-worked surfaces. A similar plot for drilling of as-cast surfaces (Fig. 5) does indicate acceptable economy. The economy of drilling pre-worked surfaces with specially-ground drills could be improved by special fixtures for grinders or construction of special grinding machines.

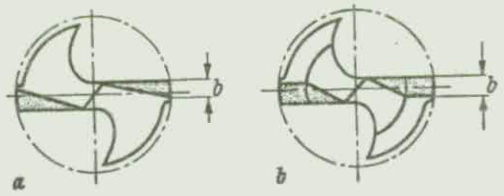


FIG. 1. Formation of wear land for a) normal grind, b) special grind

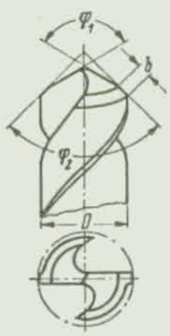


FIG. 2. Specially ground point recommended by A manufacturer

FIG. 3. Specially ground point recommended by B and C manufacturers

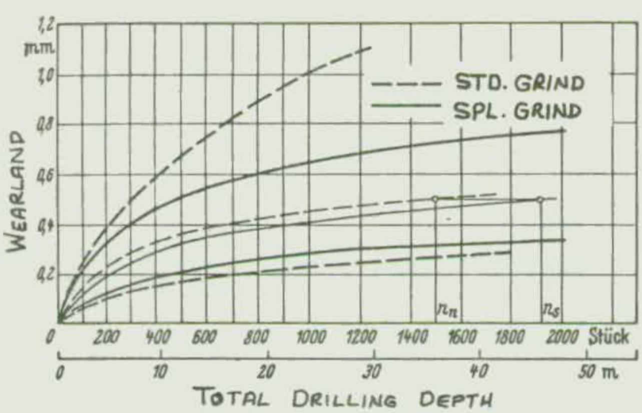


FIG. 4. Comparison in drill wear of normal and special ground drills

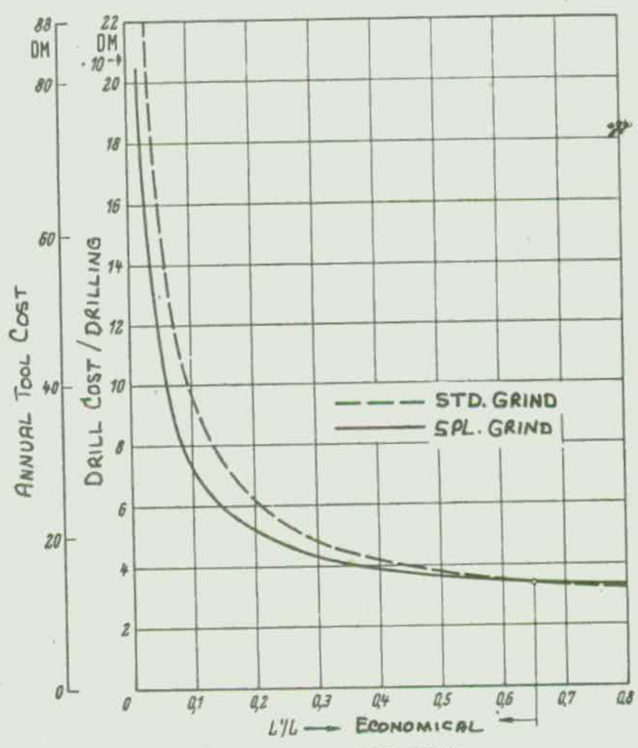


FIG. 5. Comparison of tool costs having annual production of 40,000 pieces

1. LARIN, M. N.

2. BETRIEBSMÄSSIGE PRUFUNG DER SCHNEIDEIGENSCHAFTEN VON ZERSPANUNGS-WERKZEUGEN (Testing of Cutting Properties of Cutting Tools under Factory Operating Conditions)

3. VESTNIK MASINOSTROENIJA, 1961, No. 7, pp. 66-69

4. Twist drills designated for tool life testing were obtained from various producers and were tested on a random sample basis under factory conditions. Criteria characteristics necessary to judge the quality of the different brands were determined by statistical methods. Cutting speed, feed, depth of cut and other parameters were held constant.

   Distribution curves based on calculated representative random samples were determined and are shown in Fig. 1 and Fig. 2. Analysis of the results show considerable scatter with regard to tool life. The tool life of the 16 mm drills produced by factory G is 1.3 times as high as the tool life of drills produced by factory O with similar scatter. The tool life of 9.2 mm drills produced by factory G is 1.53 times as high as tool life of drills by tool factory T. Scatter of the G-drills is four times as high as that of the T-drills.

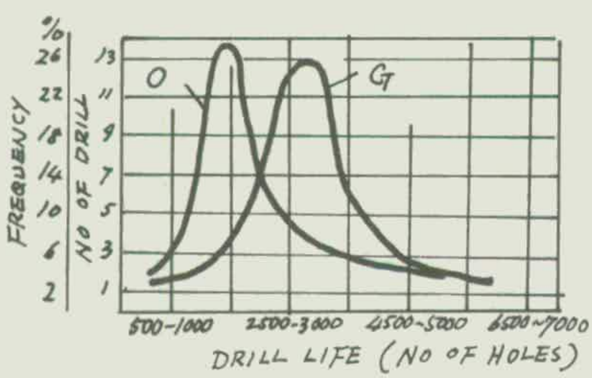


FIG. 1. Distribution curve of tool life for twist drill diameter 16 mm, work material steel Ш x 15, depth of cut 8 mm, velocity 15.7 m/min, feed 0.158 mm/rpm

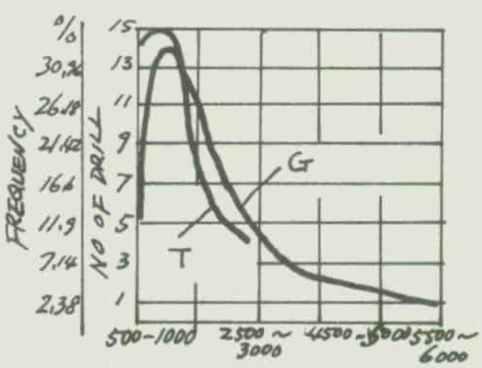


FIG. 2. Distribution curve of tool life of 9.2 mm diameter twist drills. Work material steel Ш x 15, depth of cut 13.1 mm, velocity 9 m/min, feed 0.165 mm/rpm

1. TROESTER, VON P.

2. VERSCHIEDENE SPIRALBOHRER-ANSCHLIFFARTEN UND IHRE PROBLEMATIK IN DER PRAXIS (Different grinding methods of twist drills and their practical problems)

3. WERKSTATT UND BETRIEB, 1961, Vol. 94, No. 3, pp. 137-140

4. The main criteria of a twist drill are:

   1) Unfavorable relationship between chisel edge and lip edge in cutting

   2) Sensitiveness of the corner of lip edge.

   The chisel edge works under different conditions which can not be met with other cutting tools. The chisel edge acts like a stamp and scrapes the workpiece rather than cuts. The center of the edge has zero cutting speed and only squeezes the workpiece.

   The corner of the edge works under a large cutting speed. It will be affected by two factors other than the friction which causes wear:

   1) The end of a lip edge forming a chip.

   2) The action of grinding the drill at the beginning of the point face.

   These factors are the two essential reasons for the sensitiveness, even though the corner gives a better cutting geometry as compared with a chisel edge.

   For a long time most attempts have been made for the improvement of drill points by applying the above criterion to the lip and corner edge.

   The chisel edge has to have a stable connection with both torque and thrust. Reducing the chisel edge can reduce thrust advantageously; on the other hand, it increases the risk of a failure of the chisel edge.

   A well designed drill grinding machine for drill pointing was already developed in the U.S.A. by 1914. In Germany, the same type of machine evolved in 1918/19 and by 1927 a grinding

machine for grinding of small size drills was on the market. The development of grinding machines was a result of extensive research, results of which are still effective for present day use.

Fig. 1 shows an example of the "cone pointing" method. This kind of pointing has several advantages:

1) Most applicable variations in point angle and relief angle, which are used in industry, can be easily employed.

2) Suited for different industrial work materials in a large range.

3) Large resistance capability for varied drilling condition.

4) Ease of manufacture.

Examples of web thinning are introduced in Fig. 2. Web thinning has been known since 1929. At that time the advantages of the thinning process were introduced in technical journals. The purpose of web thinning is to reduce the thrust force during drilling and also improve the relationship between lip and chisel edge.

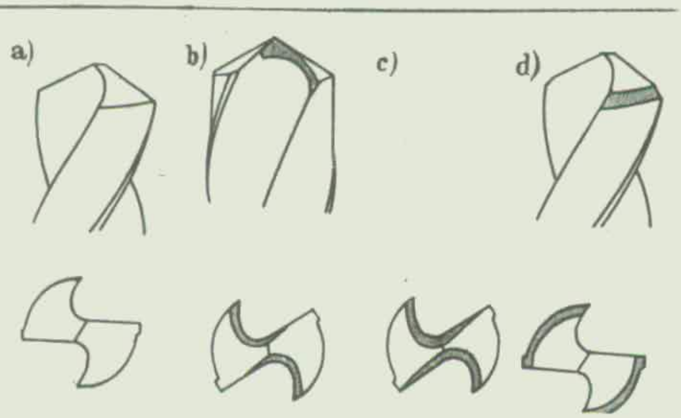


FIG. 1. Examples of point grinding

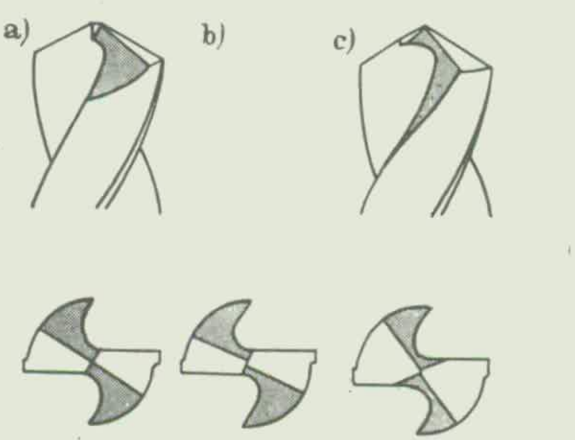


FIG. 2. Examples of web thinning

1. TSUEDA, M., HASEGAWA, Y. and KIMURA, H.

2. ON WALKING PHENOMENON OF DRILL

3. TRANSACTION OF JAPAN SOCIETY OF MECHANICAL ENGINEERS, 1961, Vol. 27, No. 178, pp. 816-825

4. The walking phenomenon of the conventional twist drill in the drilling operation was discussed. The main results obtained were as follows:

    1. The chisel edge angle seems to have a considerable effect upon walking.

    2. With decreasing feed rate, the number of corners in a drilled hole increases; however, the effect of RPM is small (Fig. 1).

    3. By using a coolant, the number of corners in a drilled hole decreases.

    4. Thrust force decreases if the walking phenomenon begins.

    5. The deflection and force at the end of a drill generates an elliptical form as shown in Fig. 2.

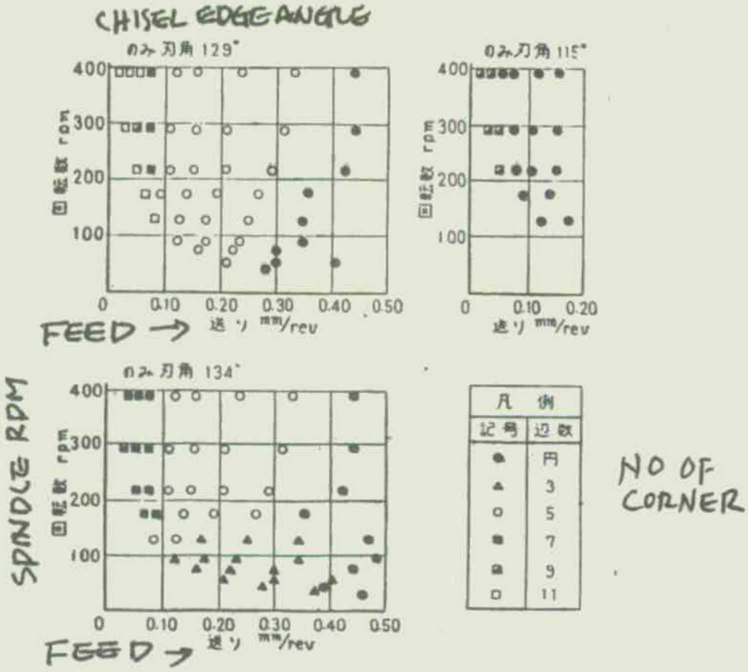
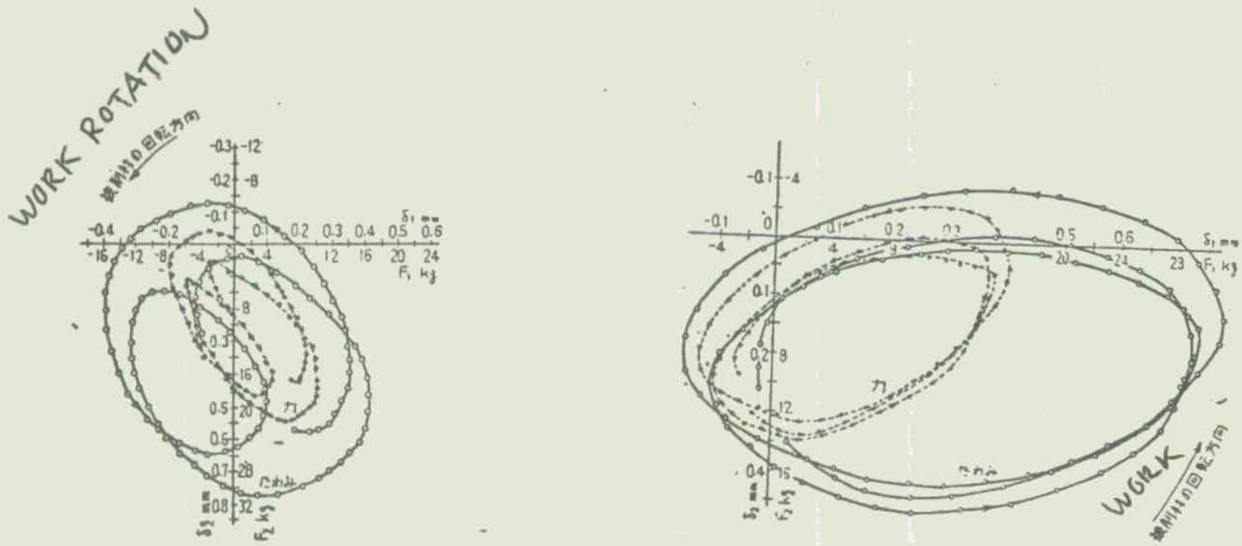


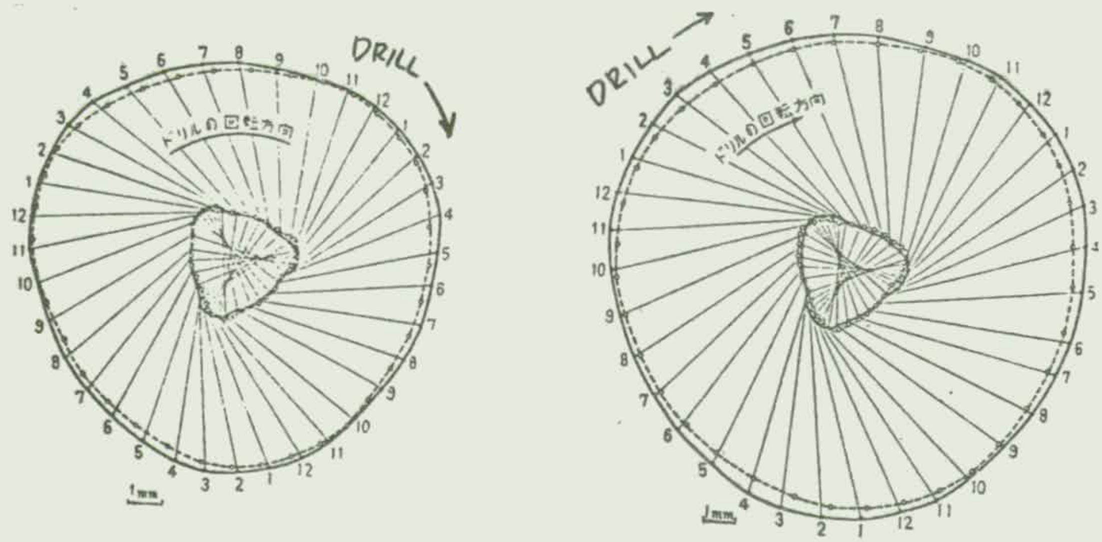
FIG. 1. Number of corners in drilled hole under different drilling conditions



CHISEL EDGE ANGLE : 126°
RPM : 80
FEED: 0.303 mm/rev

CHISEL EDGE ANGLE : 131°
RPM : 80
FEED: 0.224 mm/rev

FIG. 2. Deflection and force at the end of drill



RPM: 80
FEED: 0.224 mm/Rev

RPM: 80
FEED: 0.303 mm/Rev

FIG. 3. Loci of the Drill Walking

1. SPUR, G. and PAHLITZSCH, G.

2. MESSUNG UND BEDEUTUNG DER RADIALKRÄFTE BEIM BOHREN MIT SPIRAL-BOHRERN (Measurement of Radial Forces in Drilling and their Significance)

3. MICROTECNIC, 1961, Vol. 15, No. 2, pp. 62-64

4. Using a 3 component drill dynamometer developed by the authors, radial force in addition to torque and thrust force are investigated as functions of various parameters. The components of forces occurring in drilling can be illustrated as shown in Fig. 1. The resultant vectors of all forces reduced to the rotational axis of the drill are indicated in the figure. One is due to a balanced cutting force distribution on both lips, the other to an unbalanced force distribution on the lips. In the latter case, a radial force is in evidence.

The results of investigation are shown as follows:

1) Effect of non-uniform length of lip edge on radial force and oversize (Fig. 2).

2) Effect of feed rate on radial force (Fig. 3).

3) Effect of point angle on the radial force and oversize (Fig. 4).

The authors attempt to compare theoretical oversize caused by radial force with measured oversize and obtained sufficient agreement.

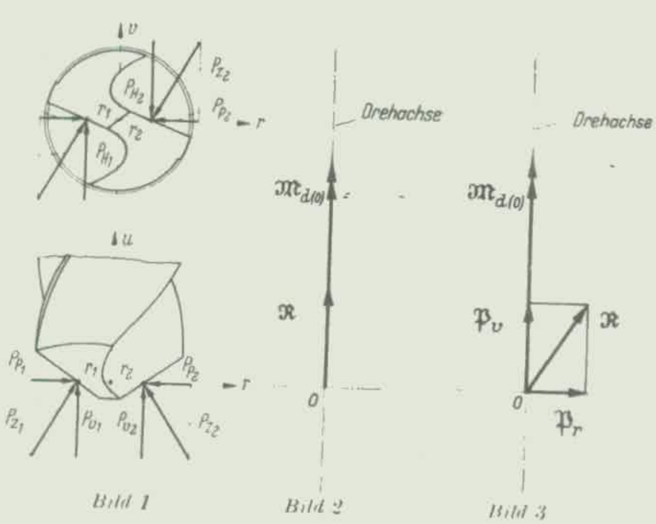


FIG. 1. Drill force components

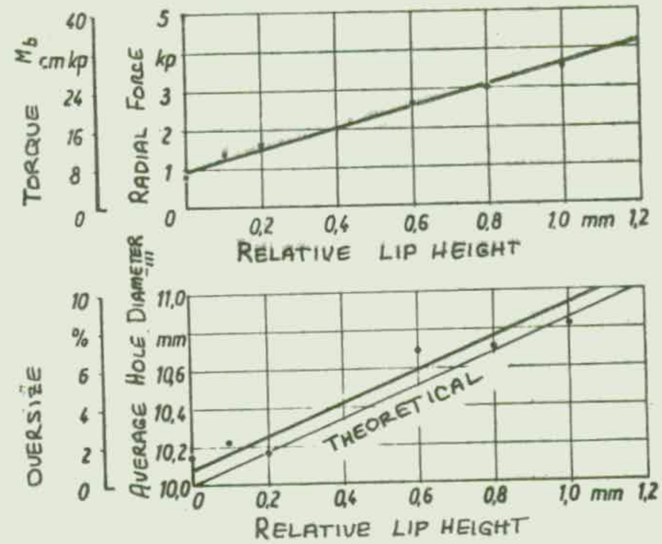


FIG. 2. Effect of non-uniform lip length on radial force and oversize

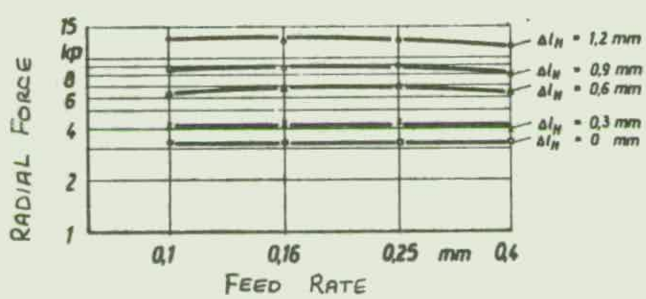


FIG. 3. Effect of feed rate on radial force

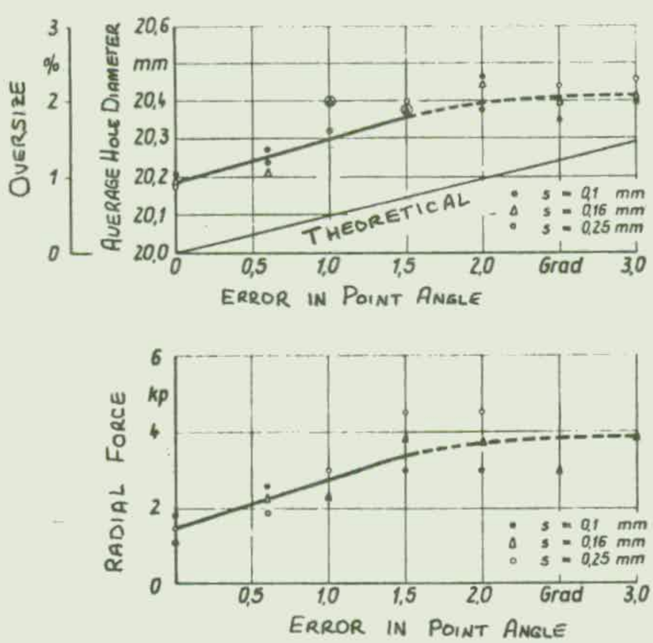


FIG. 4. Effect of non-uniform point angle on radial force and oversize

1. PAHLITZSCH, G. and SPUR, G.

2. ENTSTEHUNG UND WIRKING VON RADIALKRÄFTEN BEIM BOHREN MIT SPIRAL-BOHRERN (Formation and effect of radial forces in drilling)

3. Werkstattstechnik, 1961, Vol. 51, No. 5, pp. 227-234

4. The radial forces in drilling with a twist drill can be caused by tool, work and machine. Moreover, the radial forces due to rotation and the system can be distinguished.

The sources of rotating radial force can be listed as follows:

1) Error of rotation
2) Unsymmetric grinding of drill
3) Non-uniform sharpness of drill
4) Built-up edge
5) Break-out of one lip

The magnitude of radial force during drilling may fluctuate because of

1) Inhomogeneous workpiece
2) Fixed force
3) Non-uniform cooling

The radial forces due to the system can be caused by

1) Slope of workpiece surface to the spindle axis
2) Slope of spindle to work surface
3) Eccentricity of bushing
4) Imperfect centering

Fig. 1 shows the basic types of rotating radial forces, whose magnitudes are changed differently during drilling. An example is shown in Fig. 2, in which torque, thrust force and radial forces are recorded by a three component dynamometer.

There are many possibilities to obtain an error when grinding twist drills as shown in Fig. 3.

The effect of drilling speed is indicated in Fig. 4 and effect of feed rate and oversize of the drilled hole are introduced in Fig. 5.

The effect of depth of hole on the radial force and the hole oversize are shown in Fig. 5.

The author also investigated radial force with different drill diameters. In Fig. 6 it is shown that with large drill diameters and soft materials the hole oversize became larger.

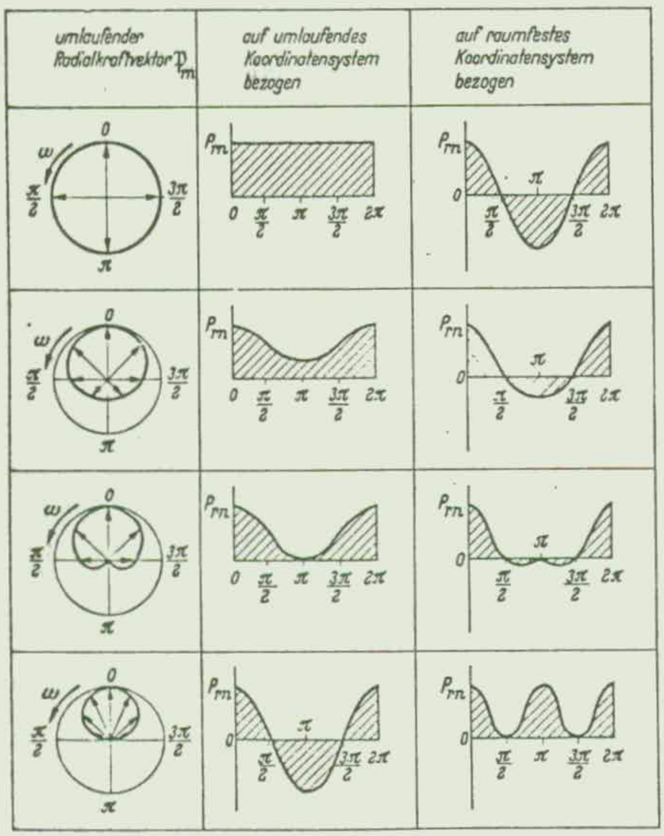


FIG. 1. Drilling force components

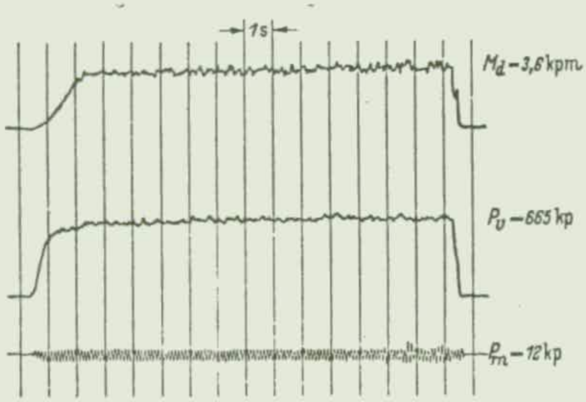


FIG. 2. Three components records of drilling forces

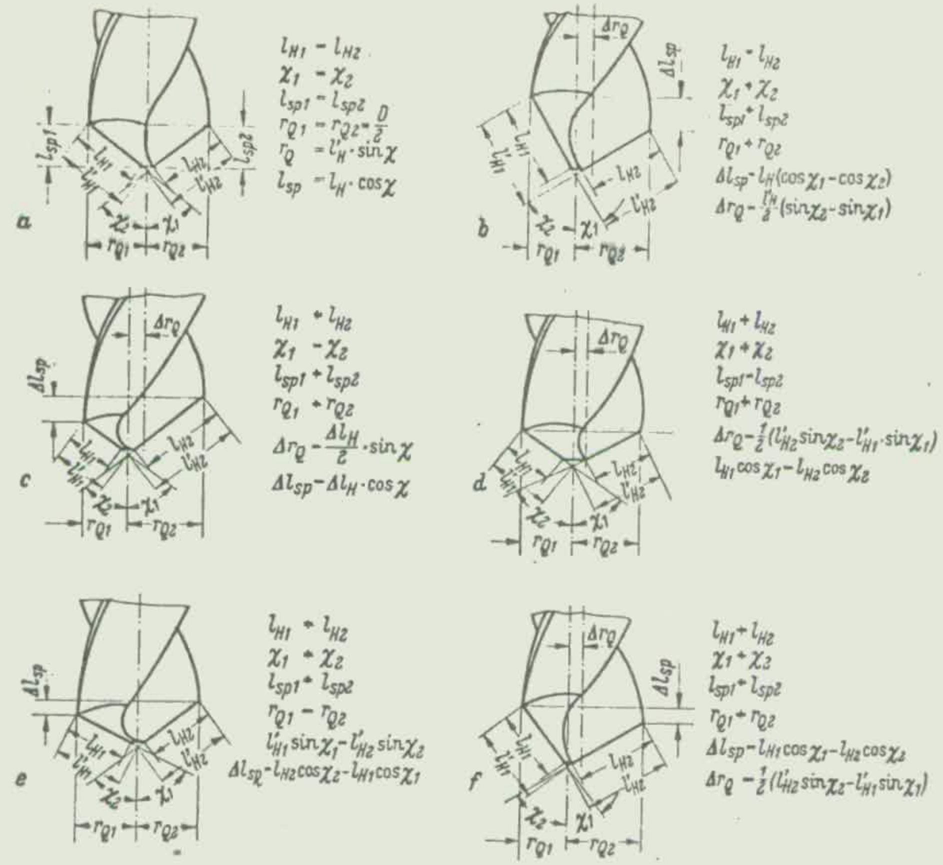


FIG. 3. Error in geometry by point grinding

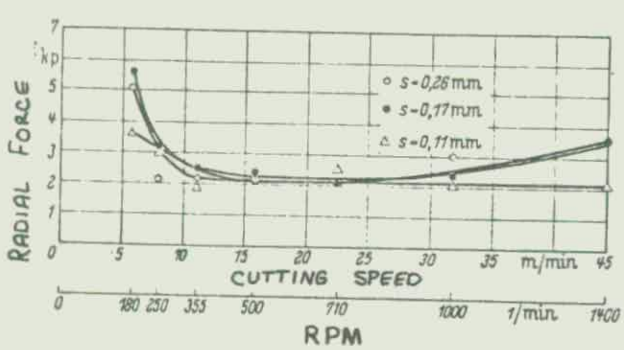


FIG. 4. Radial forces vs. drilling speed

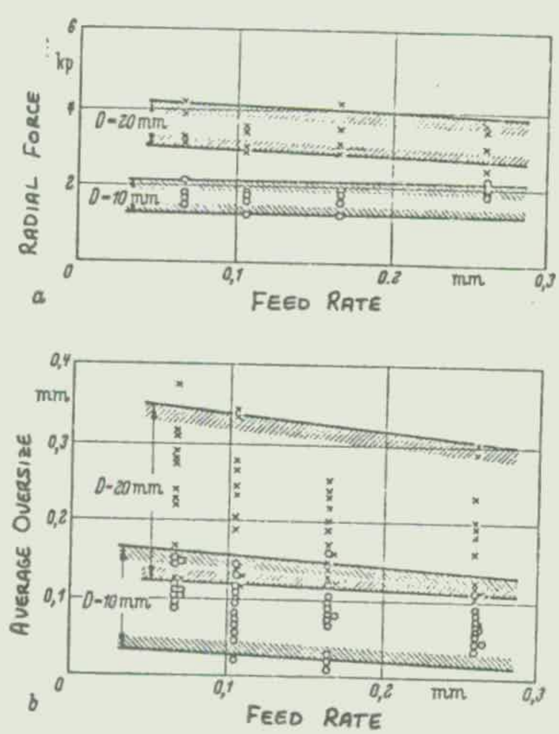


FIG. 5. Relationship between radial forces and oversizes

1. ANONYMOUS

2. CUTTING TOOL EVALUATION
1 - FUNDAMENTALS OF TESTING

3. Reprinted from METAL CUTTINGS published by National Twist Drill & Tool Co., 1961, Vol. 9, No. 4, pp. 1-7

4. When conducting tool life tests it is important that additional factors are not introduced that will affect the results.

To reduce unwanted effects the drills should be accurately sharpened and rigid fixtures and machine tools should be used. When cutting fluids are used they should be changed frequently to insure that they are fresh and of the correct consistency.

When accelerated life tests are run it must be determined that there is a predictable relationship between speed, feed and tool life.

An example of a possible error that can occur in accelerated tool life tests is shown in Fig. 1 where it can be seen that there are two distinct curves. The test was conducted at a constant speed in an alloy steel.

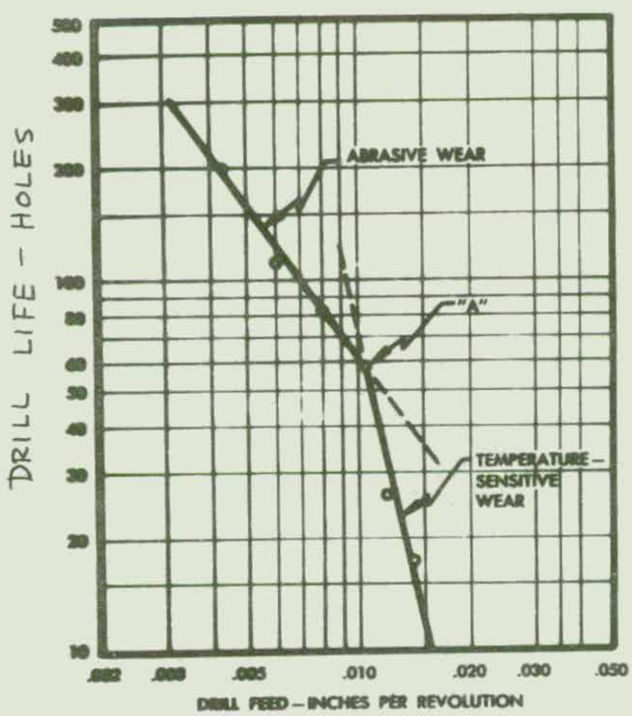


FIG. 1. Effect of drill feed upon drill life

1. HAGGERTY, W. A.

2. EFFECT OF POINT GEOMETRY AND DIMENSIONAL SYMMETRY ON DRILL PERFORMANCE

3. INT. JOUR. OF MTDR, 1961, Vol. 1, No. 1/2, pp. 41-58

4. The author discusses the advantages of the spiral point drill over the standard chisel edge drill and the effects of relative lip height and web eccentricity on hole size and drill life.

   The spiral point drill does not have the tendency to "walk" as it enters the workpiece and consequently produces holes that are closer to the desired size. A comparison of hole oversize produced by spiral point and chisel point drills is shown in Fig. 1.

   The thrust for the spiral point drill is 15 to 34 percent lower than that for chisel point drills with the greatest improvement being found at lower feeds.

   The effect of relative lip height on hole size is shown in Fig. 2.

   Web eccentricity has an effect on hole size and drill life. This is shown in Fig. 3 and 4 where it is shown that as the eccentricity increases, the hole oversizes increases and the drill life is reduced.

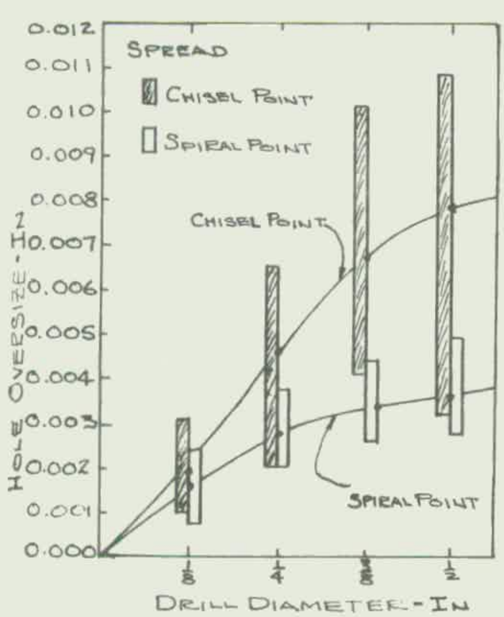


FIG. 1. Comparison of oversized holes produced by spiral point and chisel edge drills

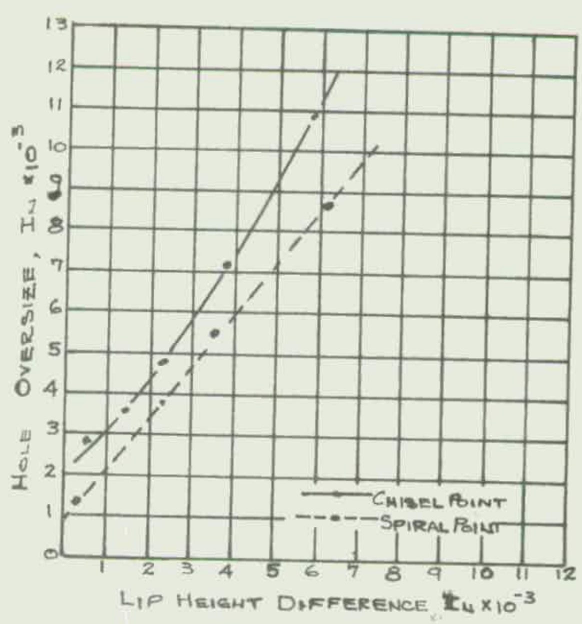


FIG. 2. Effect of lip height difference on hole oversize

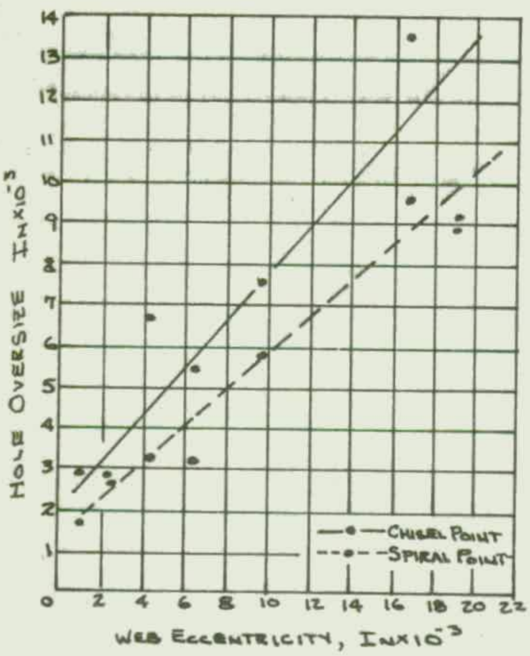


FIG. 3. Effect of web eccentricity on hole oversize

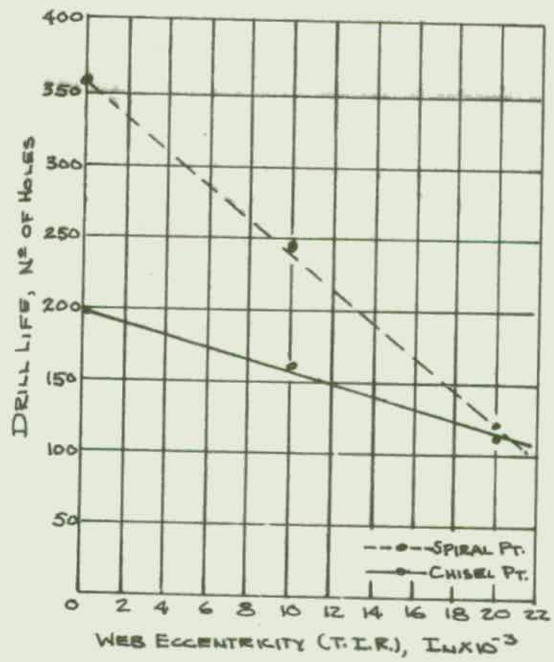


FIG. 4. Effect of web eccentricity on drill life

1. PAHLITZSCH, G. and SPUR, G.

2. EINFLUSS DER AUSKRAGLÄNGE VON SPIRALBOHRERN AUF DEN STANDWEG
(The effect of flute length of drills on the drill life)

3. WERKSTATTSTECHNIK, 1961, Vol. 51, No. 9, pp. 455-458

4. With decreased flute length of a drill, the static and dynamic stiffness were increased and it was supposed that the drill life would also be increased. From the disposition, an appropriate investigation was conducted using a step-like shiftable drill fixture as shown in Fig. 1.

By shortening of flute length from l_k = 170 mm to l_k = 92 mm, the drill life was increased approximately four times (Fig. 2). A similar fixture for shortening the flute length was developed in the U.S.A. as shown in Fig. 3. It was recommended this kind of fixture be applied where a large number of relatively small depth holes are to be drilled.

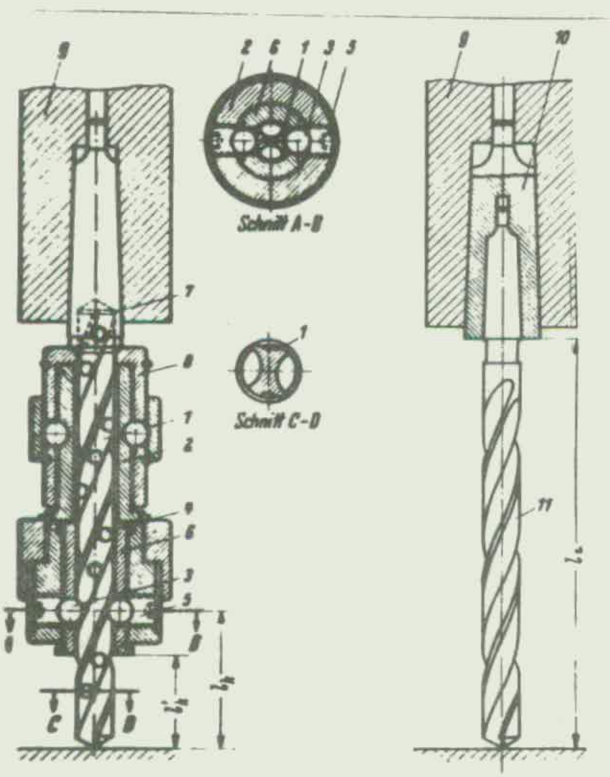


FIG. 1. Step-like shiftable drill fixture

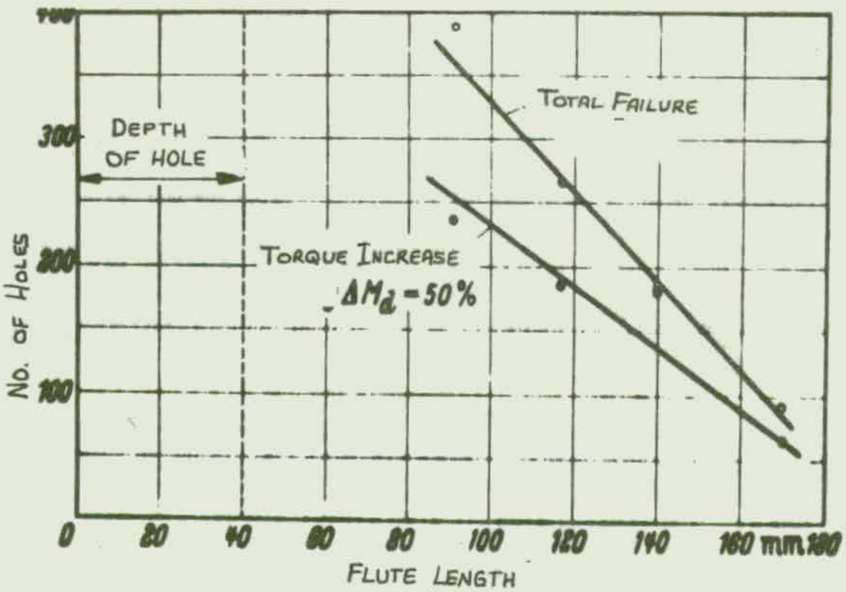


FIG. 2. Effect of flute length on drill life

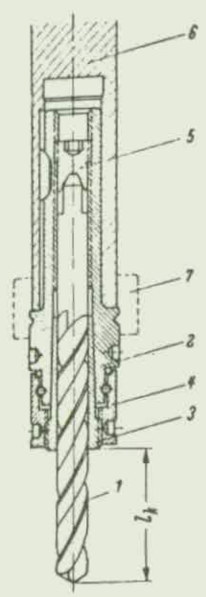


FIG. 3. Fixture for shortening the flute length

1. TSUEDA, M., HASEGAWA, Y. and NISINA, Y.

2. THE STUDY OF THE CUTTING TEMPERATURE IN DRILLING (1) ON THE MEASURING METHOD OF CUTTING TEMPERATURES

3. TRANS. JAPANESE SOCIETY OF MECHANICAL ENGINEERS, 1961, Vol. 27, No. 181, pp. 1423-1430

4. By welding several fine constantan wires on the drill flank, a drill-constantan thermocouple was formed. By measuring the temperature on the drill flank the temperature at the cutting edge was found by extrapolation.

   The experimental set-up and the results of the extrapolation technique obtained by the authors is presented in Fig. 1. Incorporating this technique, along with the tool-work and thermocolor methods, the authors compared the drill lip temperature distributions. The experimental results are portrayed in Fig. 2 and show general agreement among the various techniques.

   Using thermo-sensitive paints or, as they are sometimes referred to, thermocolors, the authors determined temperature distribution on a drill flank. The results obtained by this method are introduced in Fig. 3.

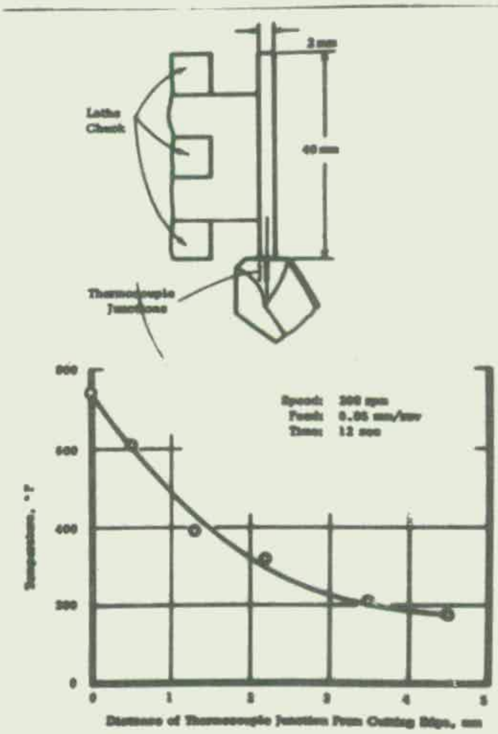


FIG. 1. Extrapolation method

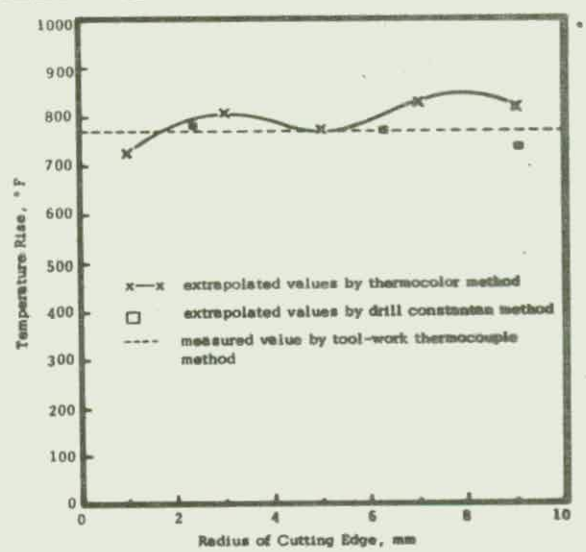


FIG. 2. Comparison of various measuring techniques

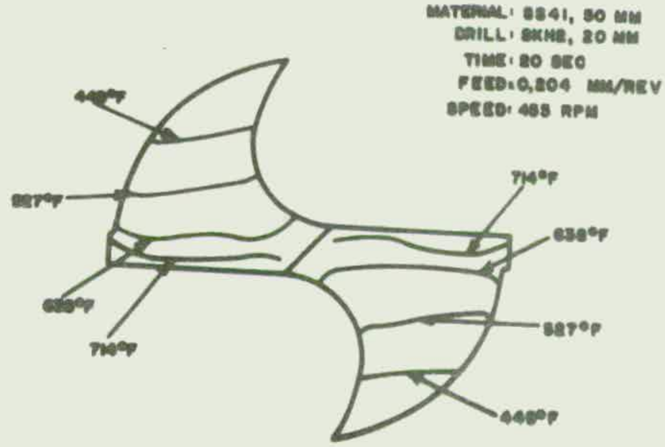


FIG. 3. Drill flank temperature distribution obtained by the thermocolor method

1. KASAHARA, H. and KINOSHITA, N.

2. EXPERIMENTAL STUDIES OF CUTTING TEMPERATURES OF DRILLING BY TWIST DRILLS

3. REP. INST. PHYS. CHEM. RES., 1961, Vol. 37, No. 3, pp. 177-185

4. Kasahara and Kinoshita varied the tool-work thermocouple method by placing a sheet of aluminum foil between phenol resin boards, shown in Fig. 1. This allowed them to obtain a temperature distribution from the chisel edge to the drill periphery. This distribution is shown along with the influence of cutting speed on the temperature in Fig. 2.

The temperature is shown to be highest at the chisel edge and the drill periphery. This varies from the distribution shown by Nishida et al and may indicate that the results obtained from drilling phenol resin boards does not apply to metal.

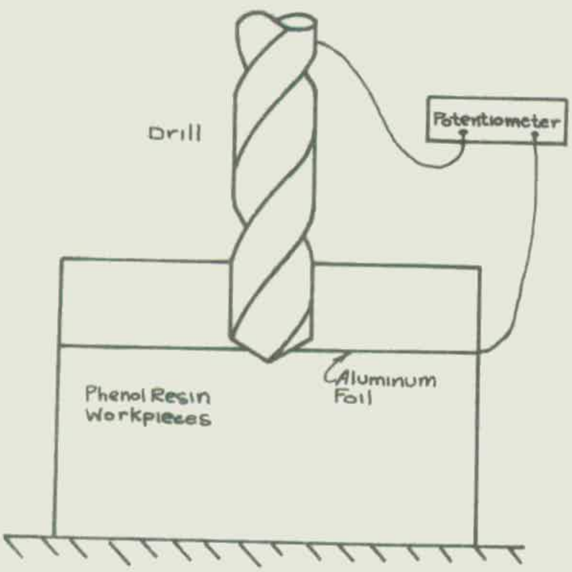


FIG. 1. Technique for measuring temperature distribution along drill lips

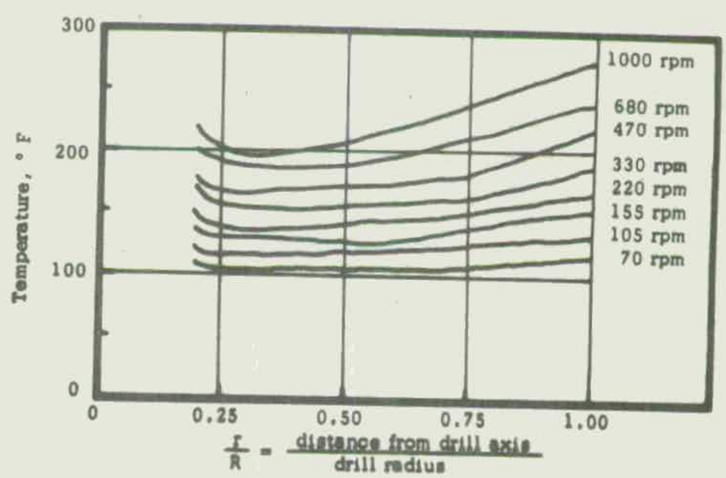


FIG. 2. Temperature distribution along drill lips

There is a considerable difference between two researchers as shown in Fig. 3.

The ratio of the temperature at the drill periphery to the temperature at the chisel edge is similar in both experimental techniques.

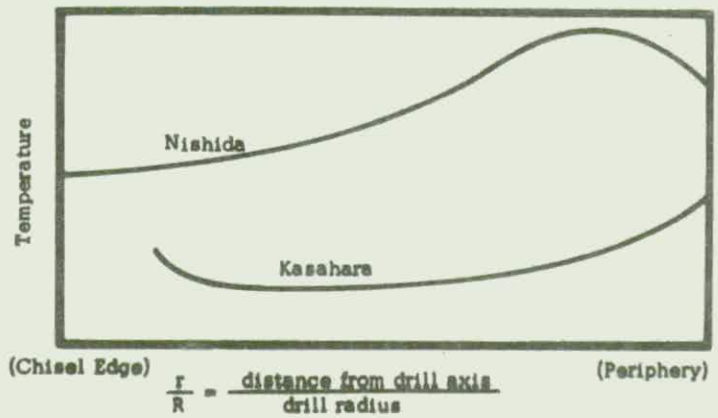


FIG. 3. Comparison of drill lip temperature distributions obtained by two researchers

1. LANDBERG, P.

2. INVESTIGATIONS IN INDUSTRY AND IN THE LABORATORY ON THE PERFORMANCE OF HIGH SPEED DRILLS AND THE EFFICIENT USE OF RADIAL DRILLING MACHINES - 1

3. MICROTECHNIC, 1961, Vol. 15, No. 4, pp. 151-157

4. This two part report consisted of four main areas of investigation. The four areas are:

   1) Efficiency of the use of twist drills.

   2) Efficiency of the use of drilling machines.

   3) Distribution, sharpening and maintenance of drills.

   4) Effect of grinding factors on drill performance.

   It was determined that the maximum speed of a drilling machine was used only 1.5 percent of the time while in over one half of the observations the speed used was between 67 and 84 percent of the maximum.

   The maximum feeds were used in approximately 5 percent of the observed cases with just over one-half of the cases showing a feed of 63 to 83 percent of the maximum possible.

   The average power used in drilling was between 1/8 and 1/4 of the capacity of the machine.

1. LANDBERG, P.

2. INVESTIGATIONS IN INDUSTRY AND IN THE LABORATORY ON THE PERFORMANCE OF HIGH SPEED DRILLS AND OF THE EFFICIENT USE OF RADIAL DRILLING MACHINES - 2

3. MICROTECHNIC, 1961, Vol. 15, No. 5, pp. 183-190

4. This second part of the report deals with factors affecting drill performance as established in laboratory experiments.

   It was found that drills that were accurately ground without a difference in lip height not only produced more holes before wear became a factor, they also produced more accurate holes.

   Tests were conducted on drills as received from the manufacturer and then on the same drills after being accurately resharpened. The accurately sharpened drills produced approximately three times as many holes as the "as received" drills and with more accuracy.

   The number of holes produced by drills from different drill manufacturers not only varied, the ranking also varied when using different materials.

   Web thinning was found to decrease the required thrust force and increase the torque. The number of holes drilled with "thinned" drills showed a significant increase over regular drills.

1. NISHIDA, S., OZAKI, S., NAKAYAMA, S., and NAGURA, K.

2. STUDY ON DRILLING II - LIP TEMPERATURE

3. JOURNAL OF THE MECHANICAL LABORATORY OF JAPAN, 1962, Vol. 8, No. 1, pp. 59-60

4. The authors used a variation of the tool-work thermocouple technique in determining temperature relationships between speed and feed. The technique used (Figs. 1 and 2) also allowed a determination of the temperature measured along the drill lips, from chisel edge to the drill periphery, or as a function of drill penetration at a certain drill radius.

   It was found that the maximum temperature occurs at approximately 1/3 of the radius in from the drill periphery. At the periphery itself the temperature is about twice the temperature at the chisel edge.

   By using the maximum observed temperature it was found that the cutting speed had a greater effect on temperature than feed rate.

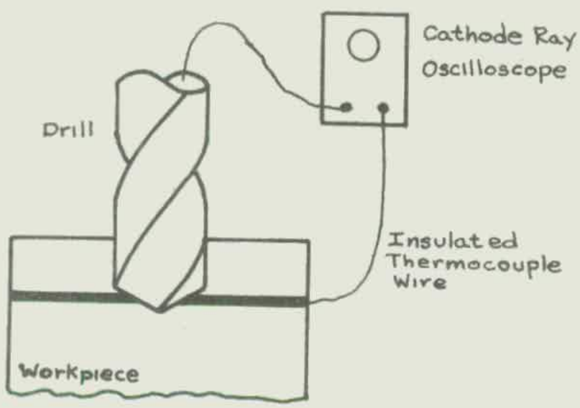


FIG. 1. Technique for measuring drill lip temperature distribution

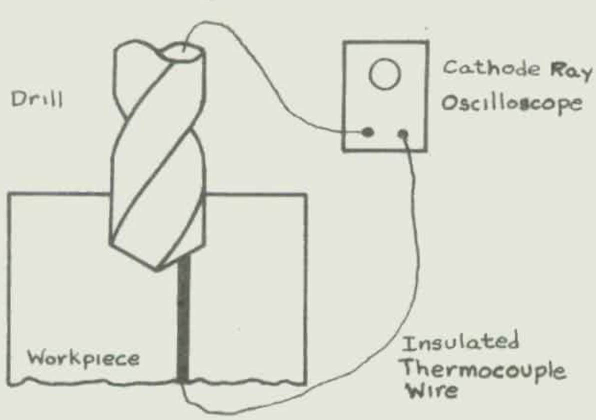


FIG. 2. Method for measuring drill temperature as a function of drill penetration

The temperature distribution along the drill lips obtained by the authors is shown in Fig. 3. This temperature distribution shows the drill lip temperature at the drill periphery to be 1.5 to 2 times that of the chisel edge. The maximum drill lip temperature was correlated with the cutting conditions of speed and feed and is illustrated in Fig. 4.

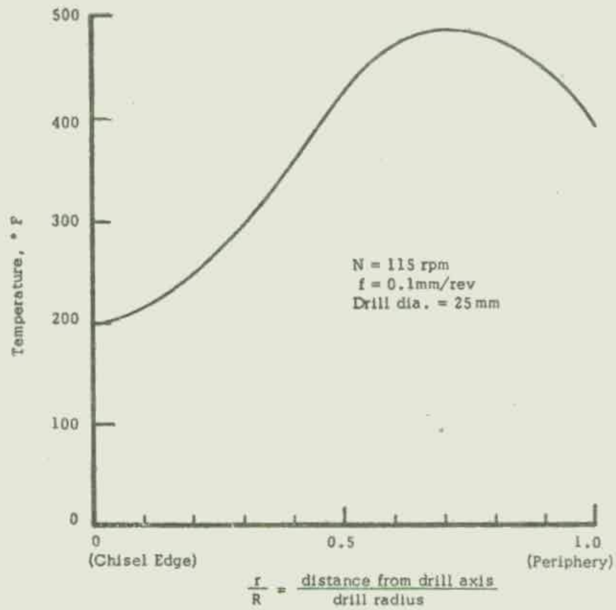


FIG. 3. Drill lip temperature distribution

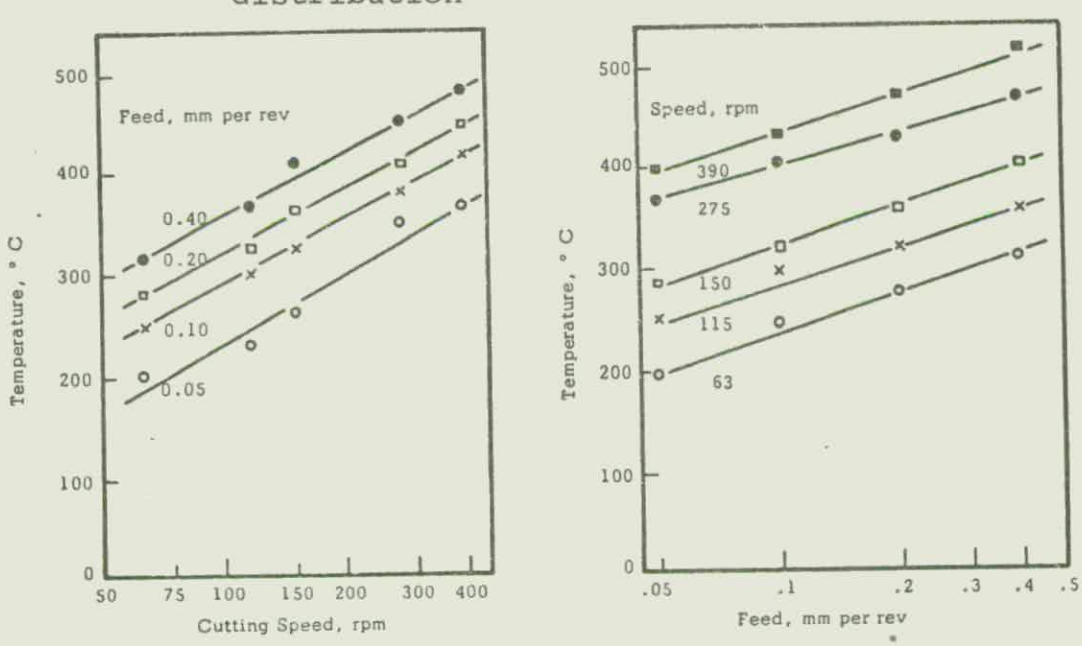


FIG. 4. Temperature vs. cutting speed and feed

1. TSUEDA, M., HASEGAWA Y., and ISIDA, Y.

2. RESEARCH ON THE TEMPERATURE RISE OF THE WORK CAUSED BY DRILLING (1) THE EFFECTS OF CUTTING CONDITIONS

3. TRANS. JAPANESE SOCIETY OF MECHANICAL ENGINEERS, 1962, Vol. 28, No. 187, pp. 384-391

4. By utilizing a work-constantan thermocouple technique (Fig. 1), Tsueda et al were able to establish the temperature distribution in a work piece. This distribution showed the highest temperature to be located under the chisel edge. (Fig. 2)

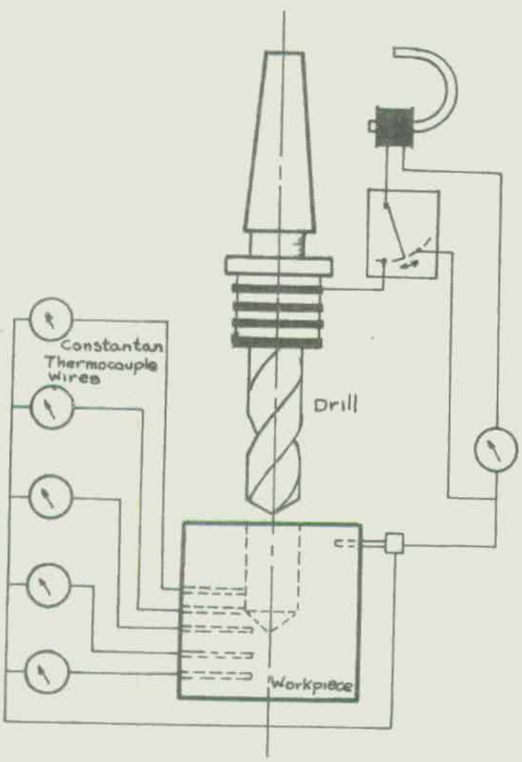


FIG. 1. Thermocouple technique to measure workpiece temperature distribution

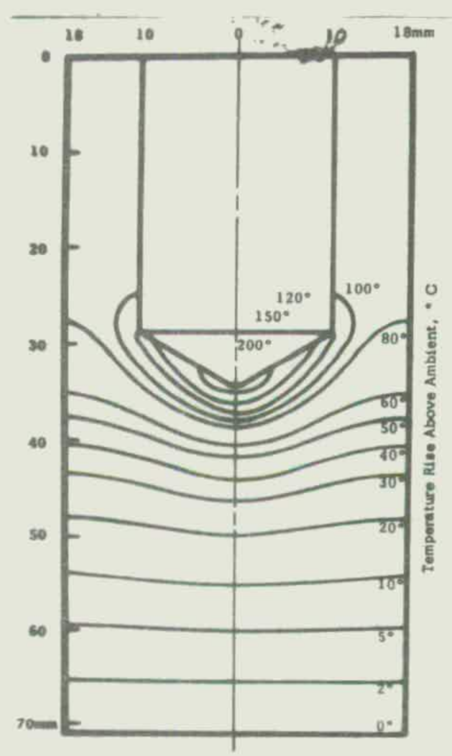


FIG. 2. Temperature Distribution

1. NOZOE, M. AND TANAKA, H.

2. STUDIES ON DRILLING - ESPECIALLY ON DRILLING TEMPERATURE

3. RESEARCH REPORT, FACULTY OF ENGINEERING, KAGOSHIMA UNIVERSITY, 1962, No. 2, pp. 3-88

4. Using the tool work thermocouple method with a mercury bath pick-up, it was shown that a drill with a point angle of 118 deg. produced a higher temperature than drills with point angles of 105 deg. and 130 deg. This effect occurred (shown in Figs. 1 and 2) at higher feed rates while the effect of different point angles was not as pronounced at lower feed rates.

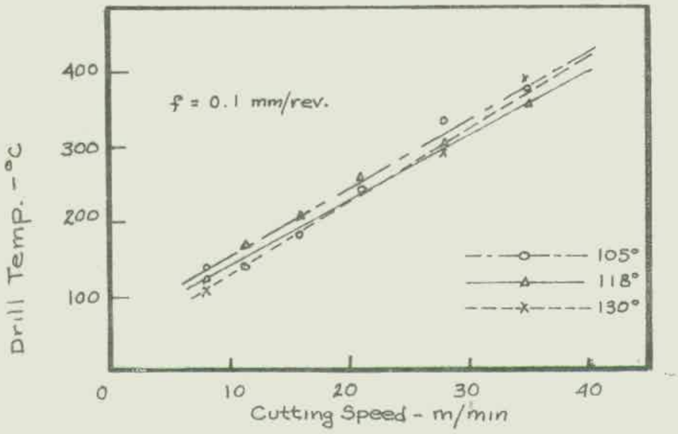


FIG. 1. Influence of drill point angle on drill temperature

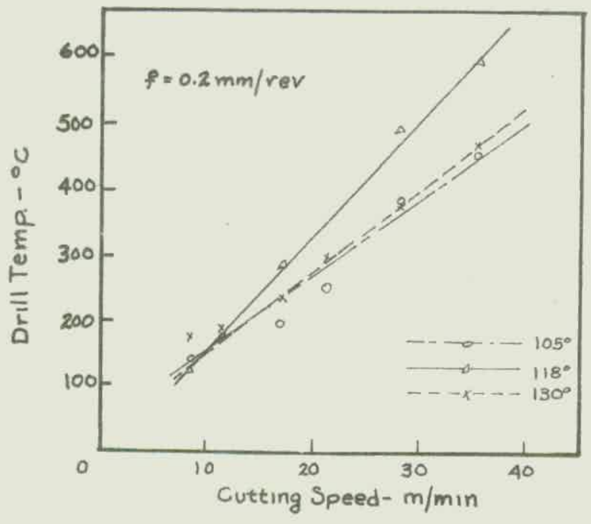


FIG. 2. Influence of point angle on temperature

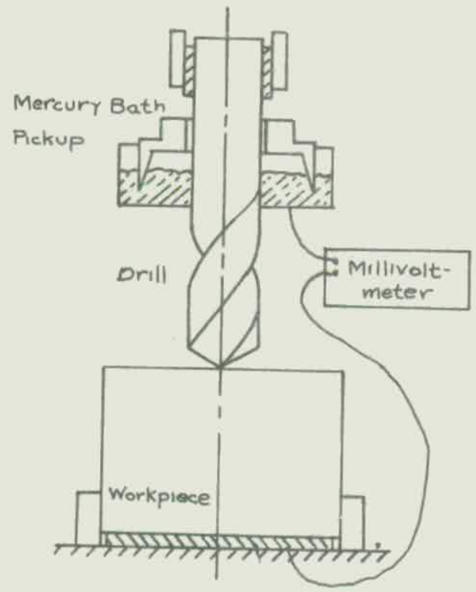


FIG. 3. Experimental apparatus
using Mercury Bath pickup

1. OXFORD, C. J., JR.

2. BALANCING DRILL COST AGAINST PERFORMANCE

3. CUTTING TOOL ENGINEERING, 1962, pp. 10-14

4. The basis for drill selection is the production of satisfactory holes at the lowest cost per hole. This indicates that the drill that might yield the lowest cost per hole on a production basis may not yield the lowest cost for a job shop operation.

   Standard catalog listed drills should be considered first for their lowest cost and for ease of inventory.

   The total cost of a machining operation is made up of four major factors. They are: a) Machining cost; b) loading, unloading and idle cost; c) tool and resharpening cost; d) tool changing cost. These costs, on a per piece basis, are plotted versus cutting speed in Fig. 1. The effect of tool life on total cost is shown in Fig. 2. The curve labeled "100" is the same total cost curve of Fig. 1.

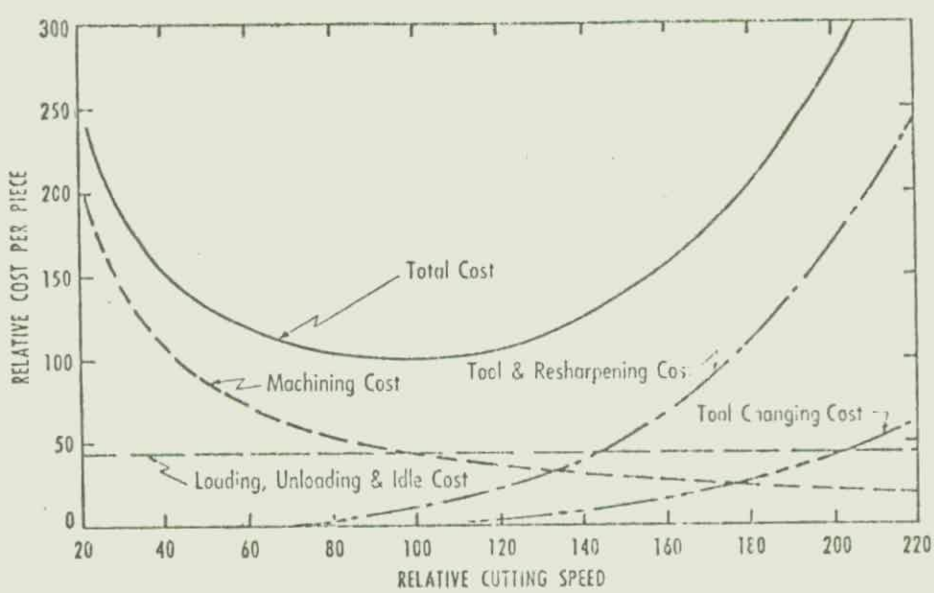


FIG. 1. Total machining cost vs. cutting speed

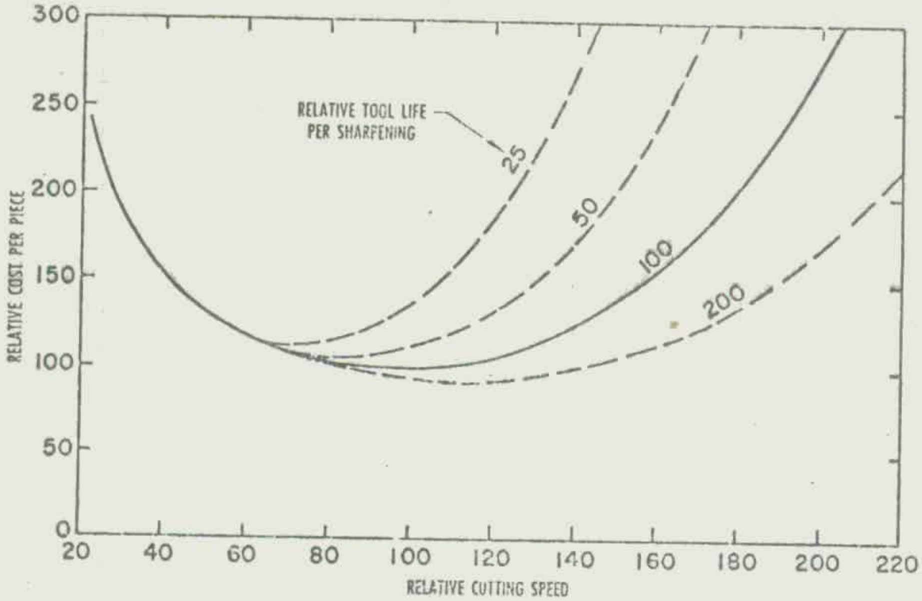


FIG. 2. Tool life vs. machining cost

1. TUEDA, M., HASEGAWA, Y., and KIMURA, H.

2. EFFECTS OF TWIST ON THE DEFLECTION DUE TO BENDING OF A TWIST DRILL AND ON THE SURFACE STRESSES DUE TO TORSION OF IT

3. TRANSACTION OF JAPAN SOCIETY OF MECHANICAL ENGINEERS, 1962, Vol. 28, No. 190, pp. 665-672

4. It is expected that a twist drill will give somewhat different results for deflection and stresses as compared with a straight bar of the same cross-section.

   Using the coordinate system and other nomenclature of Fig. 1, the deflection in the Y and Z directions and twist angle (ψ_0) can be expressed as:

$$Z = -\frac{W}{12E}\left(\frac{1}{I_y}+\frac{1}{I_z}\right)(3\ell - x)\,X^2 - \frac{W}{2E}\left(\frac{1}{I_z}-\frac{1}{I_y}\right)$$

$$\left\{ \frac{\ell - X}{4\beta^2}\cos 2(\beta X+\theta) + \frac{1}{4\beta^2}\sin 2(\beta X+\theta)\right.$$

$$\left. + X\left(\frac{\ell}{2\beta}\sin 2\theta - \frac{1}{4\beta^2}\cos 2\theta - \frac{1}{4\beta^3}\sin 2\theta\right\}\right.$$

$$Y = -\frac{W}{2E}\left(\frac{1}{I_z}-\frac{1}{I_y}\right)\left\{ -\frac{\ell - X}{4\beta^2}\sin 2(\beta X+\theta)\right.$$

$$+ \frac{1}{4\beta^3}\cos 2(\beta X+\theta) + X\left(\frac{\ell}{2\beta}\cos 2\theta + \frac{\ell}{4\beta^2}\sin 2\theta\right)$$

$$\left. + \frac{\ell}{4\beta^2}\sin 2\theta - \frac{1}{4\beta^3}\cos 2\theta \right\}$$

$$\text{and} \qquad \tan\psi_0 = \left(\frac{z - z_0}{Y}\right)_{\theta=0}$$

$$= \frac{-(\beta l - \beta X)\cos 2\beta X - \sin 2\beta X + \beta X + \beta l}{(\beta l - \beta X)\sin 2\beta X - \cos 2\beta X - 2\beta^2 l X + 1}$$

Computed and experimental values were compared and found to be in close agreement as shown in Fig. 2. For experimental purposes, strain gages were mounted on both the straight and spiral bar as shown in Fig. 3. The results shown in Fig. 4 indicate the difference in stresses for two bars which have same cross-section.

A comparison of stresses in both bars is indicated in Fig. 5.

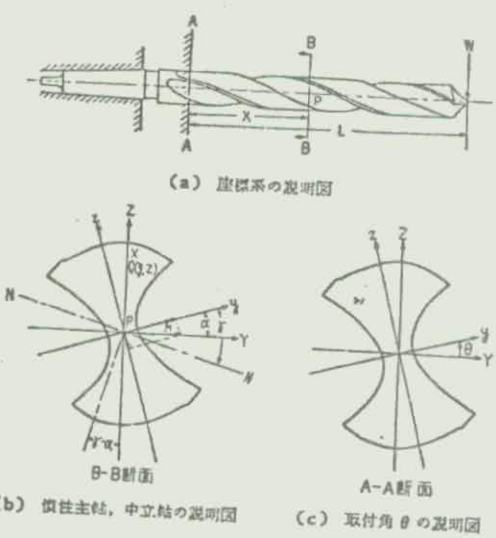


FIG. 1. Coordinate system of drill cross section

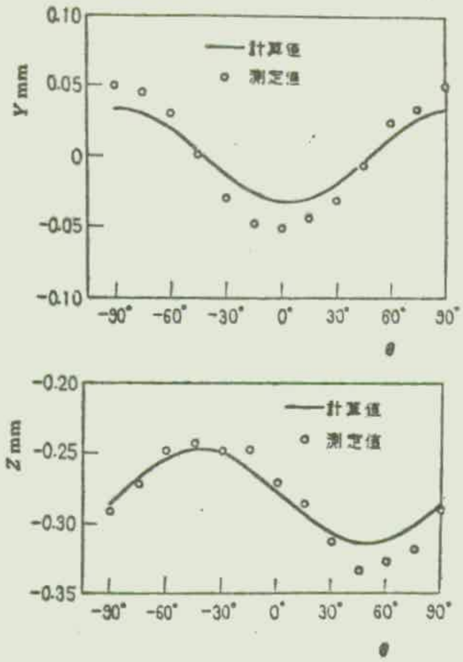


FIG. 2. Deflection of drill end

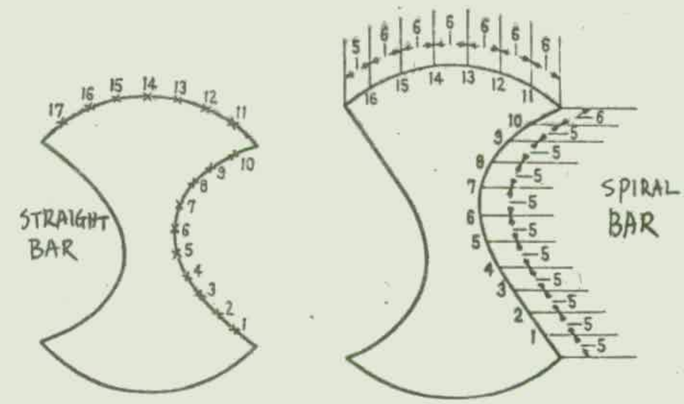


FIG. 3. Strain gage mounting for straight and spiral bar

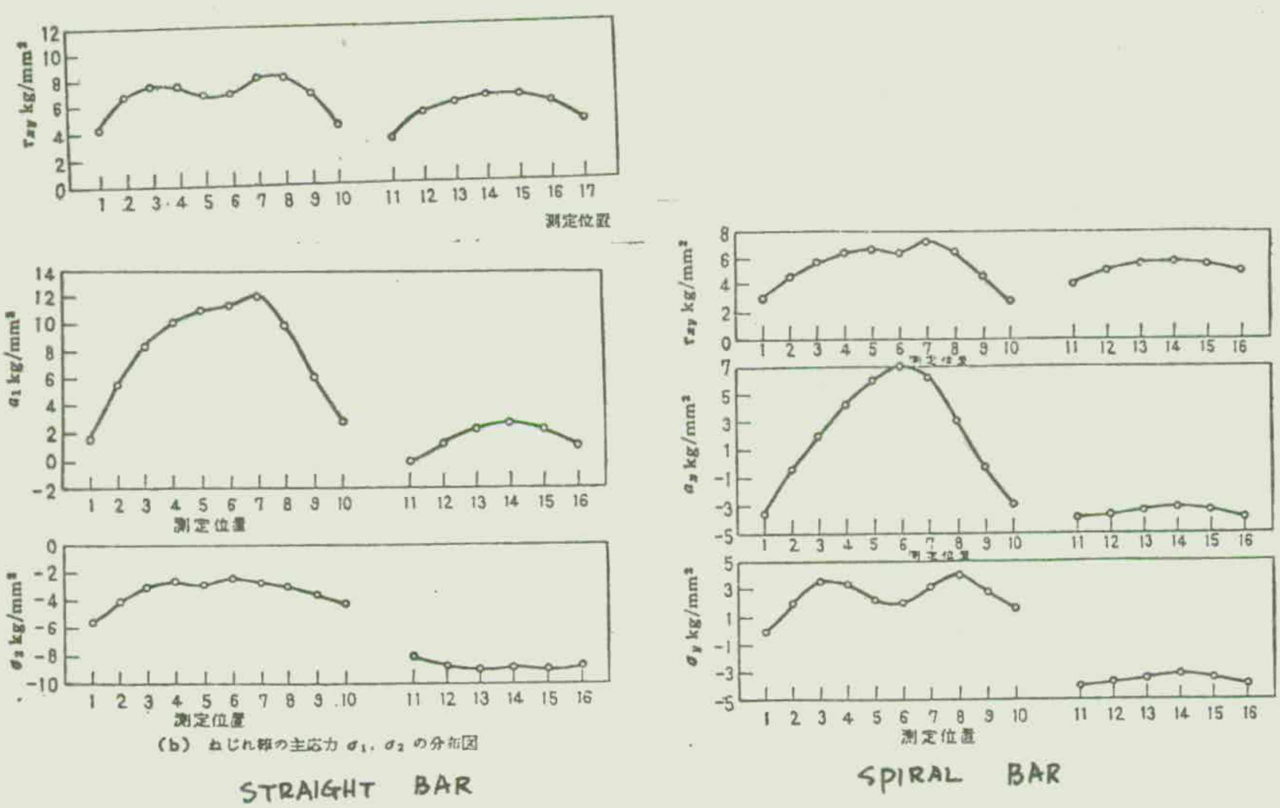


FIG. 4. Stress distribution in two different bars

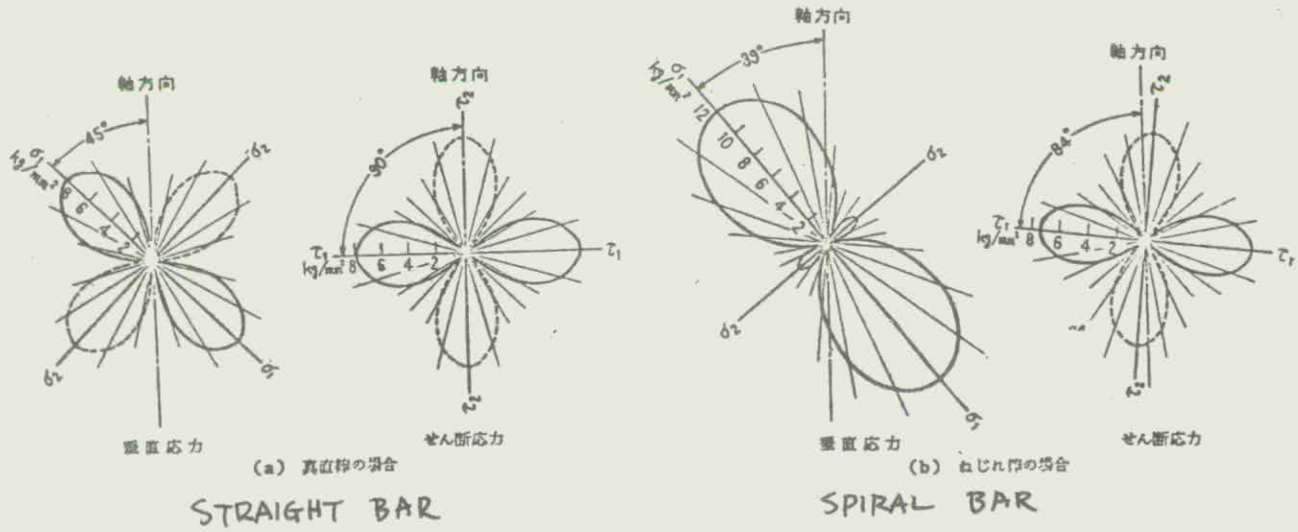


FIG. 5. Comparison of stress distribution in two different bars

1. SCHERL, M. P.

2. DRILLS RESHARPENED BY THE THOUSANDS

3. MACHINERY, 1963, Vol. 69, No. 8, pp. 115-116

4. To overcome the problem of having to resharpen a high volume of drills with unskilled labor. The problem was solved by purchasing a drill grinder that was intended for use in drill making factories.

   With this machine the operator is only required to load the drill in the machine. Lip concentricity was improved from 0.002 in. to 0.0002 in. and surface finish from 50 microns to 5 microns.

   These improvements increased tool life and eliminated a reaming operation in some processes.

1. MOERS, P. and ERFURT, E. H.

2. DER FREIWINKEL AM SPIRALBOHRER (Relief angle of twist drill)

3. INDUSTRIE-ANZEIGER, 1963, Vol. 54, pp. 1261-1262

4. In general, it is considered that the role of the relief angle in the performance of twist drills is not important. Considering the importance of the relief angle in turning and milling, its effect in drilling was tested. It was found that the effect of the relief angle on drill life was significant when drilling different work materials as shown in Fig. 1.

   In order to precisely find the effect of the relief angle, it was necessary to grind the drill geometry, especially the point angle, helix angle and chisel edge angle.

   A relief angle measuring foil was developed as indicated in Fig. 2. This foil device can be wrapped around a drill, allowing the corner axis of the drill to serve as both reference point and line.

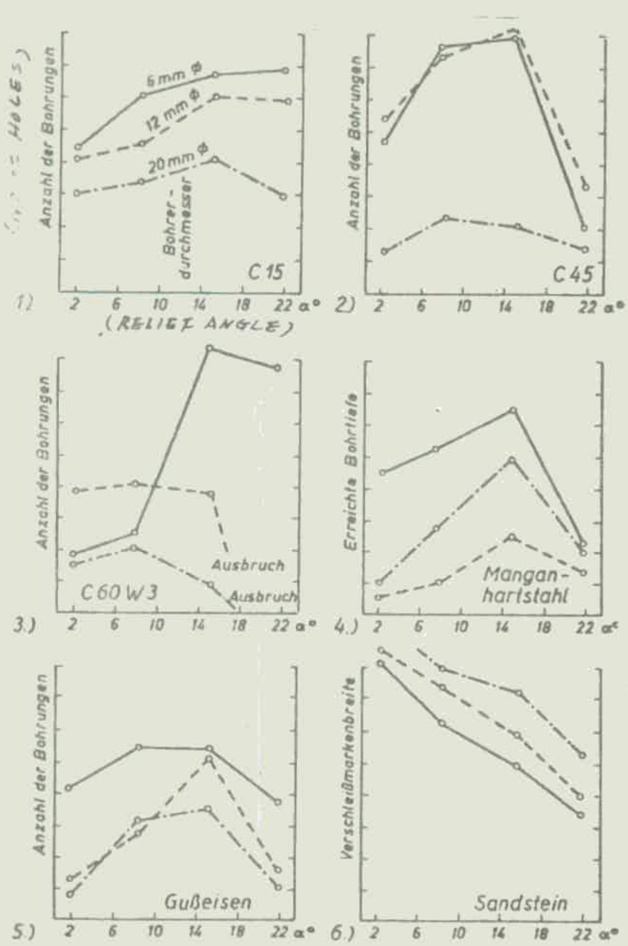


FIG. 1. Effect of relief angle on drill life

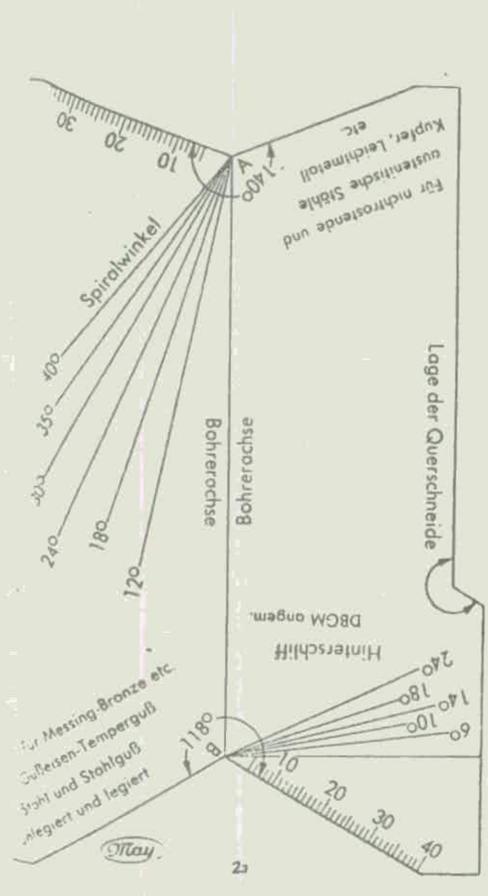


FIG. 2. Newly developed relief angle measuring foil

1. KRONENBERG, M.

2. GRUNDZUEGE DER ZERSPANUNGS LEHRE BD 2. (Machining Science and Application)

3. Published by Springer-Verlag, 1963

4. The author classified four rake angles in drill geometry:

   a) Parallel rake angle γ_p, which is produced by the cylinder of the diameter (d) as shown in Fig. 1. The formula for the parallel rake angle can be given as

   $$\tan \gamma_p = \frac{d\pi}{h} = \frac{d}{D} \cdot \tan \sigma$$

   because $\tan \sigma = \frac{D\pi}{h}$

   where σ = Helix angle

   A diagram for the parallel rake angle is presented in Fig. 2.

   b) Velocity rake angle (in direction of cutting speed) This rake angle is measured from the direction of line 2 as shown in Fig. 3 and can be expressed as

   $$\tan \gamma = \frac{d}{D} \cdot \frac{\tan \sigma}{\sin \frac{\varepsilon}{2}}$$

   where ε = point angle

   The relationship between the velocity rake angle and $\frac{d}{D}$ is indicated in Fig. 4.

   c) Oblique rake angle, γ_s, shown in Fig. 5 and expressed as

   $$\gamma_s = \frac{\tan \sigma \sqrt{\frac{d^2}{D^2} - 0{,}15^2}}{\sin \frac{\varepsilon}{2} - 0{,}15 \tan \sigma \cdot \cos \frac{\varepsilon}{2}}$$

   A diagram for this rake angle is presented in Fig. 6.

   d) Rake angle of chip flow, γ_f. Fig. 7 shows this angle and a diagram for this angle is introduced in Fig. 8. The equation for the angle can be given as

   $$\tan \gamma_f = \frac{d}{D} \frac{\tan \sigma}{\left[1 + \left(\frac{1 - \sin \frac{\varepsilon}{2}}{0{,}85} \right)\left(0{,}15 - \frac{d}{D}\right)}$$

The author has computed torque from the point of view of drill rigidity as

$$Md = 0.0865 \cdot G \cdot \vartheta \cdot r^2 [1 + 5.74 \sigma]$$

where G = Modulus of rigidity
ϑ = Twisting angle

As shown in Fig. 9, the torque and thrust force can be computed as

$$Md = P_e \frac{D}{2}$$

and $$P_e = \frac{2Md}{D}$$

The specific cutting force will be

$$k_s = \frac{P_e}{F_e}$$

where F_e = cross section of chip.

Considering the effect of feed and drill diameter, torque can be computed as

$$M_d = C_1 D^x \cdot s^y$$

and thrust force

$$P_e = 2C_1 D^{x-1} s^y$$

The general equations for torque and thrust can, therefore, be expressed as

$$M_d = \frac{C_{KSB} \cdot D^x \cdot s^y}{2^{(x+1)} \cdot 5^{\frac{1}{2}(x-y-1)}}$$

and

where $$C_{KSB} = C_1 \cdot 2^{(x+y)} \cdot 5^{\frac{1}{2}(x-y-1)}$$

and is defined as the cutting force when the drill removes a 1 mm^2 cross section of chip at a slenderness ratio of 5.

NOTE: Slenderness ratio is given as $G_e = \frac{r}{\frac{s}{2}} = \frac{D}{s}$

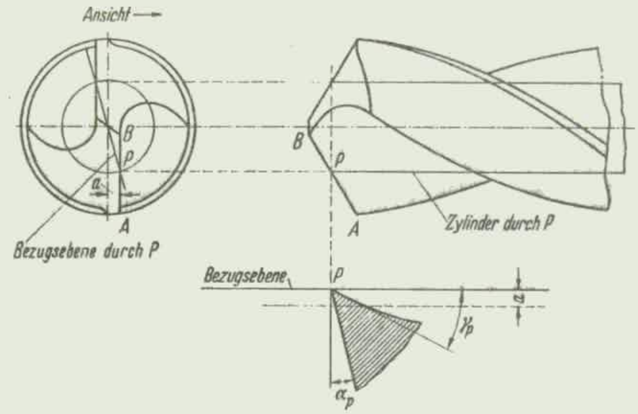


FIG. 1. Parallel rake angle at the point P

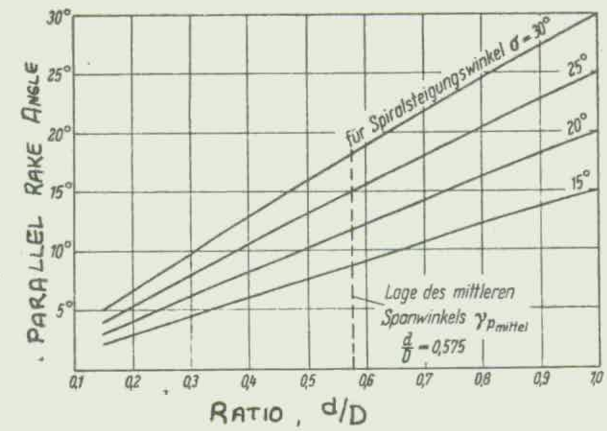


FIG. 2. Parallel rake angle depends upon diameter

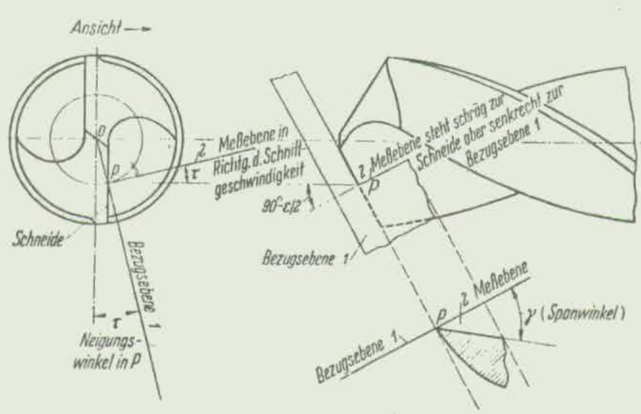


FIG. 3. Velocity rake angle at the point P

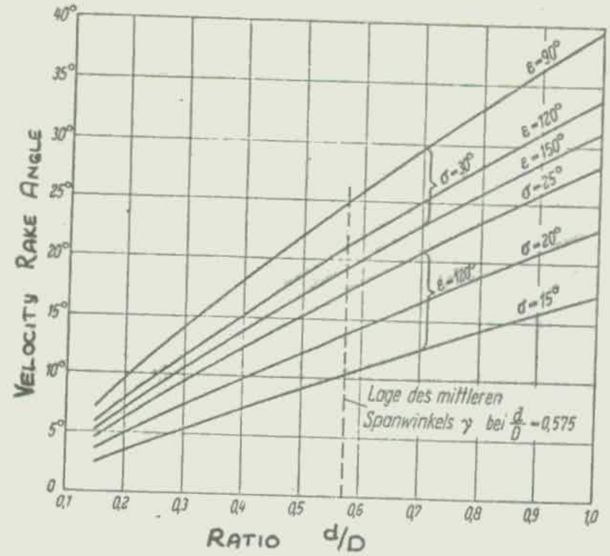


FIG. 4. Velocity rake angle depends upon $\frac{d}{D}$

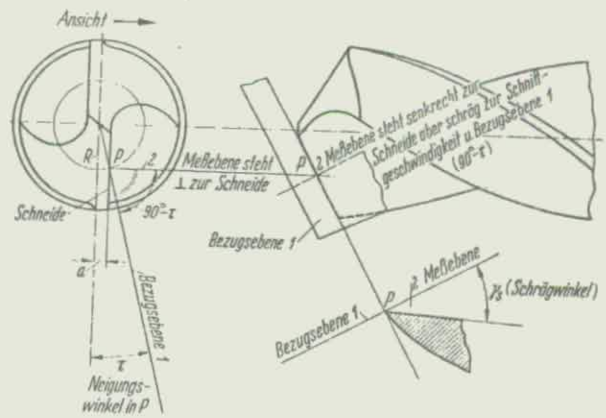


FIG. 5. Oblique rake angle at the point P

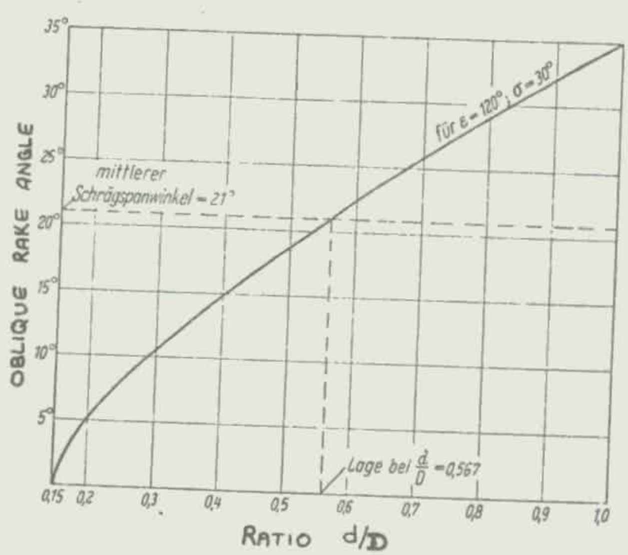


FIG. 6. Oblique rake angle depends upon drill diameter

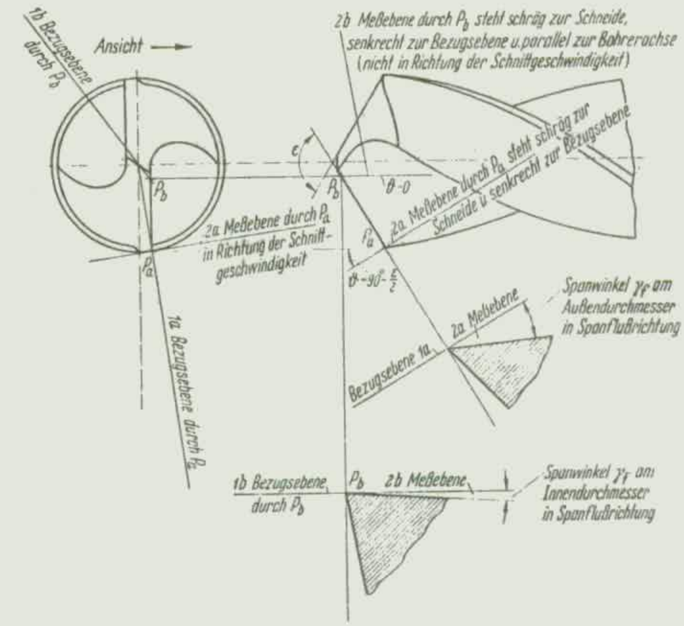


FIG. 7. Rake angle of chip flow at point P_b

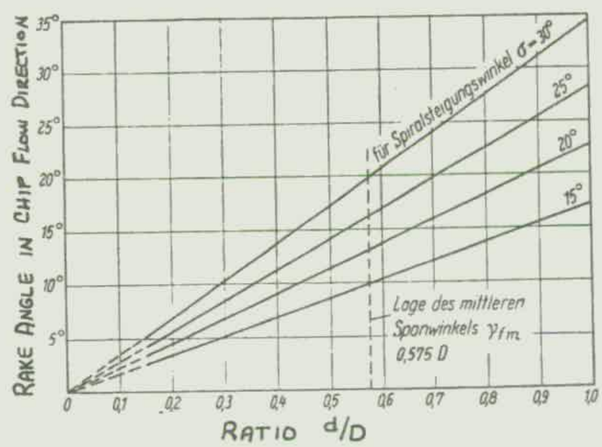


FIG. 8. Rake angle of chip flow depends upon $\frac{d}{D}$

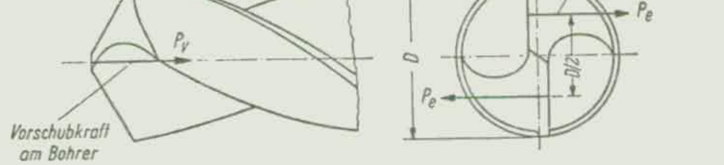


FIG. 9. Drill forces on the twist drill

1. PESLAR, E. F.

2. MODIFIED TOOLING SLASHES COST OF DRILLING TUBE SHEETS

3. MACHINERY, 1963, Vol. 69, No. 10, pp. 87-89

4. By using high pressure oil hole type twist drills and modifying the geometry, the cutting speed for drilling hot rolled AISI 1035 steel of Brinell hardness 200 was increased from 400 to 920 rpm and the feed rate from 0.006 to 0.021 ipr.

   The drill was modified by grinding a secondary relief angle in addition to the primary clearance angle and the point angle was increased from 118 deg. to 140 deg. with a secondary point angle of 90 deg. also added. The helix angle was increased from 28 to 32 deg. and the point was thinned for a distance of 1 inch from the point.

   The tool life increased from an average of 35 holes per sharpening with the standard drills to over 150 holes per sharpening with the modified drills.

1. ANDREASSON, D. and GOODYEAR, H. J.

2. AIR MIST AIDS DEEP-HOLE DRILLING

3. AMERICAN MACHINIST/METALWORKING MANUFACTURING, 1963, Vol. 107, No. 14, pp. 81-82

4. This technique combines air mist cooling with especially designed Bi-Tip oil hole drills. The drills are especially designed for each job by varying tool geometry. A two lip cutting tip is brazed to the tool body and imerge into a single flute on the OD of the drill body.

   Tests on cast iron V-8 engine blocks indicate a cutting speed of approximately 200 sfpm with the drills producing between 900 to 1000 holes that were 5 to 10 in. deep. A low quantity of liquid is required for the process with about one gallon of 18:1 per 1000 holes.

1. ARZT, P. R. and STEWART, I. J.

2. CUTTING FLUIDS FOR MACHINING AEROSPACE ALLOYS

3. LUBRICATION ENGINEERING, 1963, Vol. 19, No. 7, pp. 283-291

4. The materials have been grouped into two general classifications, structural and refractory metals.

   In Fig. 1, the effect of various cutting fluids on drill life for four classes of structural metals is given. The fluid which produced the best drill life is taken as the base for comparing the other fluids.

   Due to the fact that there is a velocity gradient along the cutting edges of a drill, the location of maximum wear can be shifted from the point to the margin by appropriate fluid selection. The best fluid results in uniform wear along the cutting edge.

   The effect of three cutting fluids on drill life when drilling the refractory metals is shown in Fig. 2.

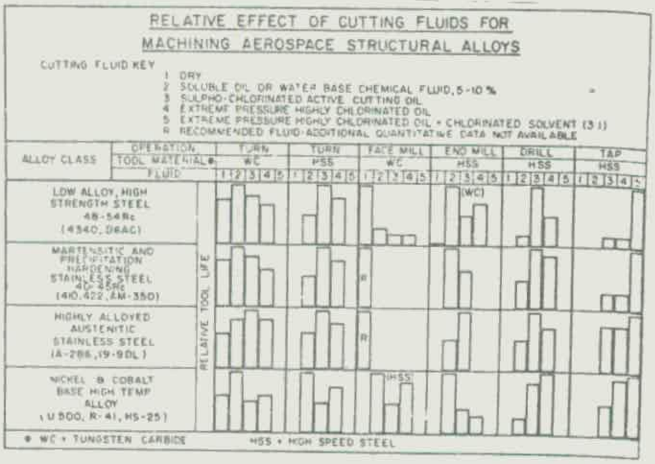


FIG. 1.

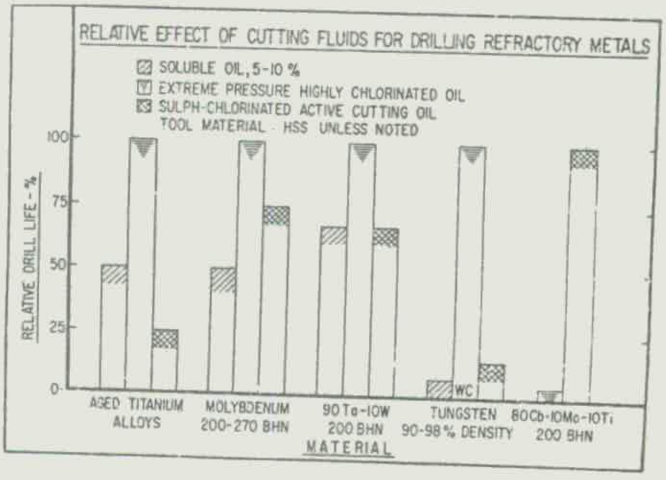


FIG. 2.

1. PAHLITZSCH, G. and SPUR, G.

2. MESSUNG UND BERECHNUNG VON DREHMOMENT UND VORSCHUBKRAFT BEIM BOHREN MIT SPIRALBOHRERN (Measurement and calculation of torque and thrust force in twist drilling)

3. INDUSTRIE-ELEKTRONIK, 1963, Vol. 11, No. 3, pp. 6-8 and
No. 4, pp. 9-10

4. Under the assumption that when drilling in a <u>solid</u> the moment arm of the couple about the point is X = 0.5D, the torque (M_d) can be obtained as

$$M_d = 0.5 \cdot D \cdot P_h$$

The total thrust force will be

$$P_v = P_{v1} + P_{v2} \quad \text{(See Fig. 1)}$$

From Kienzle's formula, the cutting force will be

$$P_h = b \cdot h^{1-z} \cdot k_{s1 \cdot 1}$$

where $b = \dfrac{D}{2 \cdot \sin\varkappa}$

$$h = \frac{s}{2} \cdot \sin\varkappa \qquad \text{(See Fig. 2)}$$

The factor $k_{s1 \cdot 1}$ and the exponent 1-z are a value of the work-material, which can be established by actual investigation. The $k_{s1 \cdot 1}$ means the specific cutting force for cross section of chips of $h \cdot b = 1 \cdot 1\ mm^2$ and the exponent 1-z indicates the rate of increase of cutting force.

From the geometrical relationship between length (b), width (h), diameter (D), feed rate (s) and point angle ($\varphi = 2 \cdot \chi$), the computation of torque can be expressed as follows:

$$M_d = \frac{D^2}{4 \cdot \sin} \left(\frac{s}{2} \cdot \sin\chi\right)^{1-z} \cdot k_{s1 \cdot 1}$$

This formula includes only the important influence factor which can be applied only under standard conditions. In order to take into consideration factors such as, pointing, pilot hole and dullness of drill, a correction factor is added to the above formula

C_1 and C_2, i.e.,

$$M_d = C_1 \cdot C_2 \cdot 0.29\ D^2 \cdot (0.43 \cdot s)^{1-z} \cdot ks1 \cdot 1$$

where

Not centered	$C_1 = 1$
Centered by 0.1 D	$C_1 = 0.95$
Predrilled to a dia. of chisel edge length	$C_1 = 0.90\text{-}0.92$
Freshly Ground:	$C_2 = 1$
Drill dullness which lets M_d increase by 50%	$C_2 = 1.5$
Drill dullness which lets M_d increase by 100%	$C_2 = 2$

Point angle = 116 - 120°

The exponent 1-z and $k_{s1 \cdot 1}$ were obtained by investigations as follows:

Werkstoff	σ_B kp/mm²	1-z	$k_{s1 \cdot 1}$ kp/mm²
St 50	55	0,82	196
16 MnCr 5	55	0,83	202
18 CrNi 8	62	0,82	269
Ck 60	85	0,87	220
34 CrMo 4	61	0,80	184
46 MnSi 4	65	0,85	239
100 Cr 6	71	0,76	278

The formula of thrust force can be expressed as

$$P_v = D \cdot h^{1-y} \cdot k_{vn1 \cdot 1}$$

where $1-y$ = Increment of thrust force

$k_{vn1 \cdot 1}$ = Specific normal forces in thrust

From Fig. 2

$$P_{vn} = \frac{P_v}{2 \cdot \sin\chi}$$

Therefore,

$$k_{vn} = \frac{P_{vn}}{b \cdot h} = h^{1-y} \cdot k_{vn1\cdot 1}$$

The 1-y and $k_{vn1\cdot 1}$ for several work materials were indicated as follows:

Werkstoff	σ_B kp/mm²	1-y	$k_{vn1\cdot 1}$ kp/mm²
St 50	55	0,74	146
16 MnCr 5	55	0,64	122
18 CrNi 8	62	0,55	124
Ck 60	85	0,57	117
34 CrMo 4	61	0,64	146
46 MnSi 4	65	0,62	136
100 Cr 6	71	0,56	163

As in the case of torque, the thrust force can be formulated as follows:

$$P_v = K_1 \cdot K_2 \cdot D \cdot (0.43 \cdot s)^{1-y} \cdot k_{vn1\cdot 1}$$

where K_1, K_2 are correction factors, and

Not centered	$K_1 = 1$
Centered by 0.1 D	$K_1 = 0.6 - 0.8$
Predrilled to the dia. of chisel edge length	$K_1 = 0.5$
Freshly ground	$K_2 = 1$
Drill dullness, which lets M_d increase by 20%	$K_2 = 1.2$
Drill dullness, which lets M_d increase by 50%	$K_2 = 1.5$

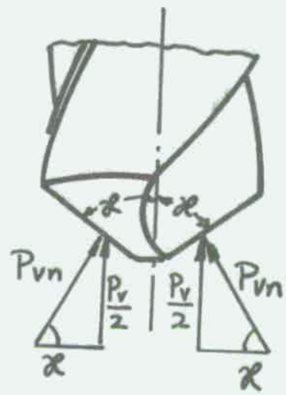


FIG. 1. Relationship between thrust force p_V and normal thrust force p_{Vn}

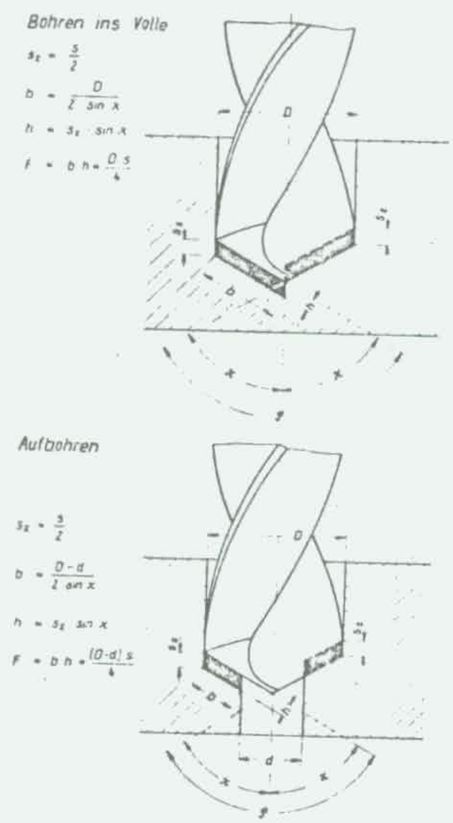


FIG. 2. Geometrical relationship in the drills

1. PAHLITZSCH, G. and SPUR, G.

2. UNTERSUCHUNGEN ÜBER DIE OBERFLÄCHENRAUHEIT DER BEIM BOHREN MIT SPIRALBOHRERN ERZEUGTEN BOHRUNGSWAND (Investigation on the Surface Roughness Obtained by the Twist Drill on the Workpiece)

3. MASCHINENMARKT, 1963, No. 88 (November), pp. 27-29

4. Drilling with twist drills belongs to the processes which do not require high accuracy, including surface roughness. In drilling steel, the highest frequency of obtainable surface roughness varies from 80 to 100 μm maximum roughness height (R_t). The variation ranges from R_t = 40 to R_t = 160 μm for 90 percent of all measured values. Surface roughness increases parabolically with cutting speed. The effect of feed rate on surface roughness is observed only at higher feed rates.

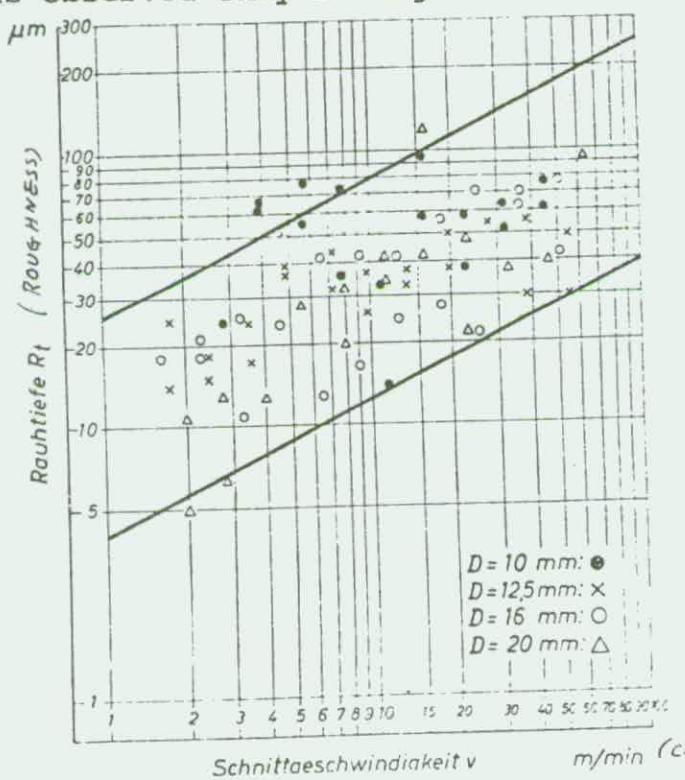


FIG. 1. Effect of Drilling speed

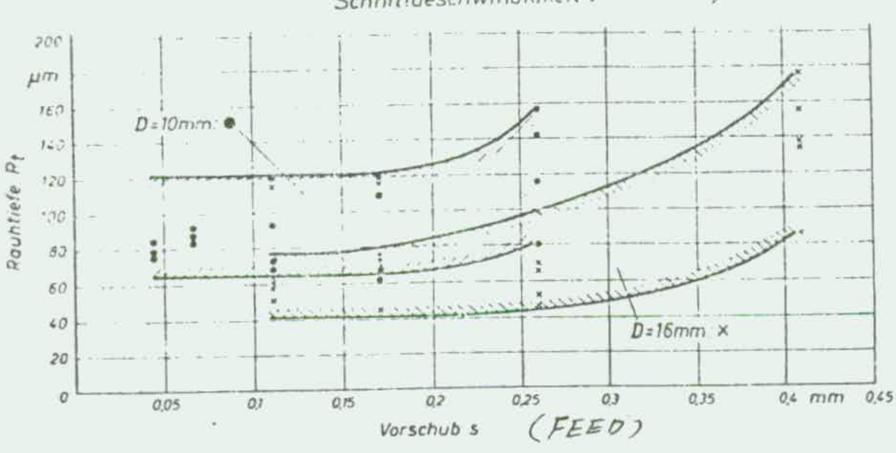


FIG. 2. Effect of feed rate

1. SPUR, G.

2. ERGEBNISSE VON SCHNITTKRAFTMESSUNGEN BEIM BOHREN MIT SPIRAL-BOHRERN (Investigation on drilling force measurement)

3. MASCHINENMARKT, Nr. 36, May 1963

4. Kienzle had previously developed the following cutting force formula

$$P_H = b \cdot h^{1-z} \cdot k_{s1 \cdot 1}$$

In drilling, the cutting force components can be analyzed as shown in Fig. 1 with the vectorial sum indicated in Fig. 2. Using a specially own developed dynamometer, investigations were conducted. The effect of drilling speed is shown in Fig. 3.

From Kinzle's formula the cutting force, P_H, in drilling can be computed considering the fact that

$$b = \frac{D}{2 \sin \varkappa} \quad , \quad h = \frac{S}{2} \cdot \sin \varkappa$$

as

$$P_H = \frac{D}{2 \sin} \left(\frac{S}{2} \cdot \sin \varkappa\right)^{1-z} \cdot k_{s1 \cdot 1}$$

The effect of width of chip, b, and thickness of chip, h, were obtained as shown in Fig. 4 and 5. The thrust force, P_V, also computed as

$$P_V = 2 \cdot b \cdot h \sin \varkappa \cdot k_{vn} = 2 \cdot b \cdot \sin \varkappa \cdot h^{1-y} k_{vn1 \cdot 1}$$

where

$$P_{vn} = \frac{P_V}{2 \cdot \sin \varkappa}$$

and

$$C = \frac{P_V}{2 \cdot \sin \varkappa \cdot b \cdot h} = \frac{P_{vn}}{b \cdot h} = k_{vn}$$

Specific cutting force k_s and specific normal force k_{vn} are introduced in Figures 6 and 7.

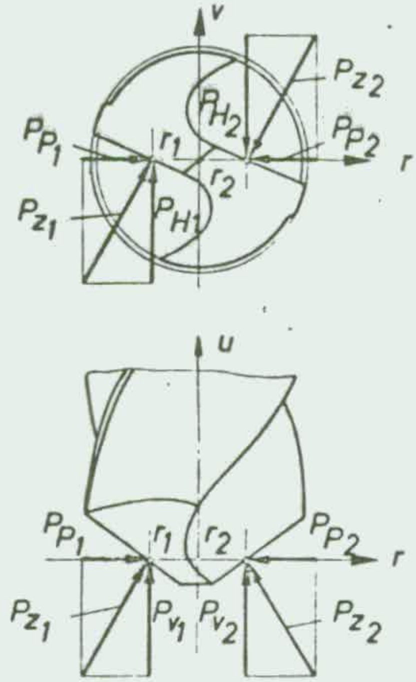


FIG. 1. Drilling force components

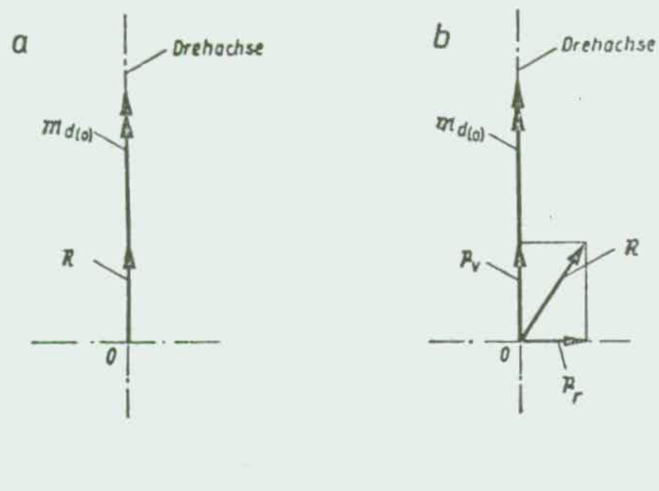


FIG. 2. Vectors of drilling resultant forces

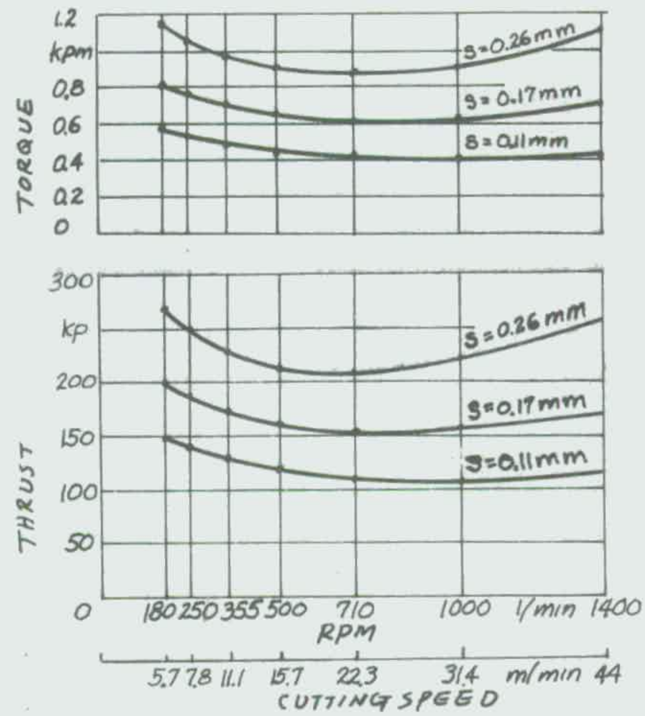


FIG. 3. Effect of cutting speed on drilling forces

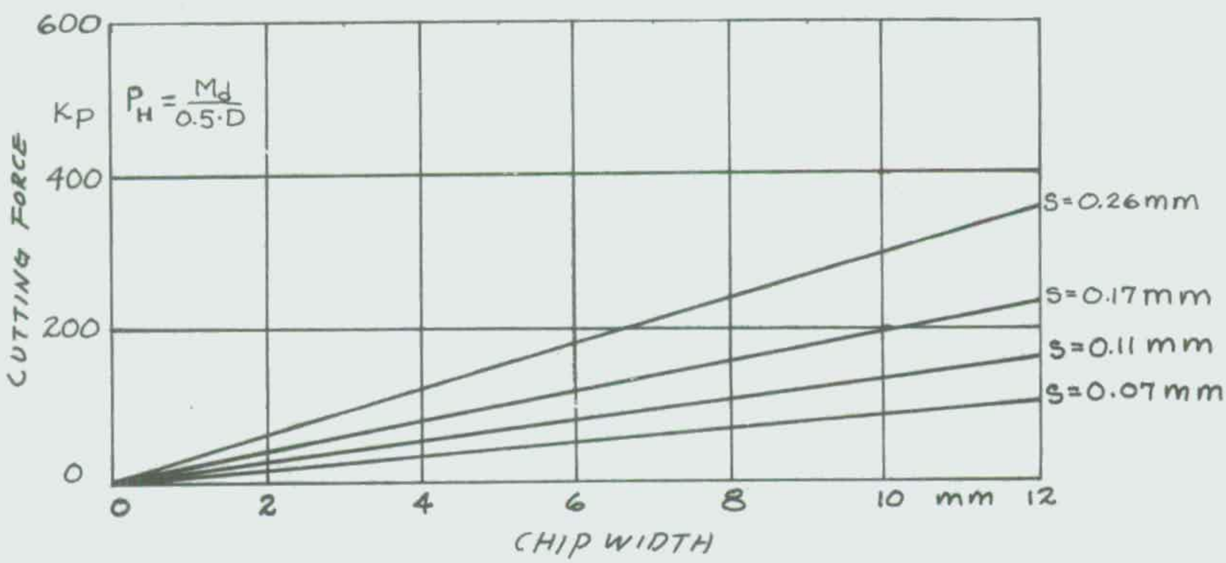


FIG. 4. Effect of chip width on the cutting forces

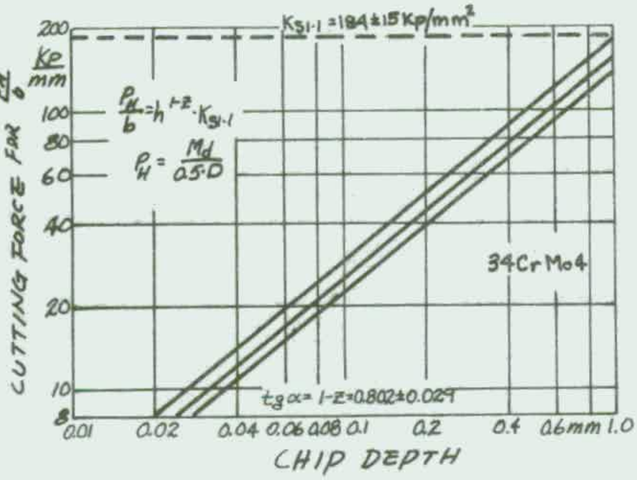


FIG. 5. Effect of chip depth on specific cutting forces

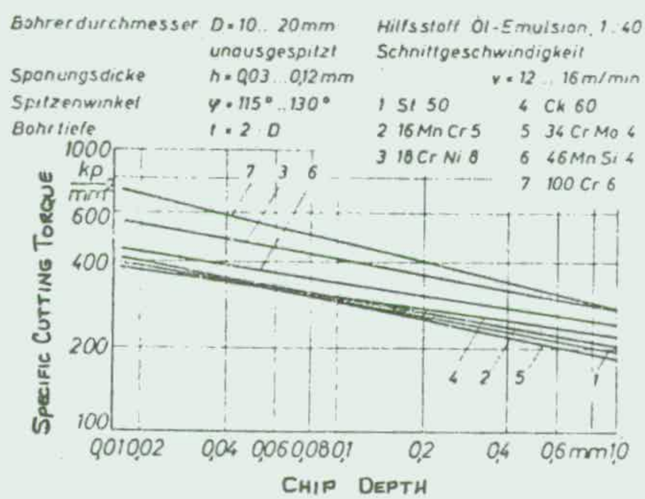


FIG. 6. Specific cutting forces depend upon chip depth

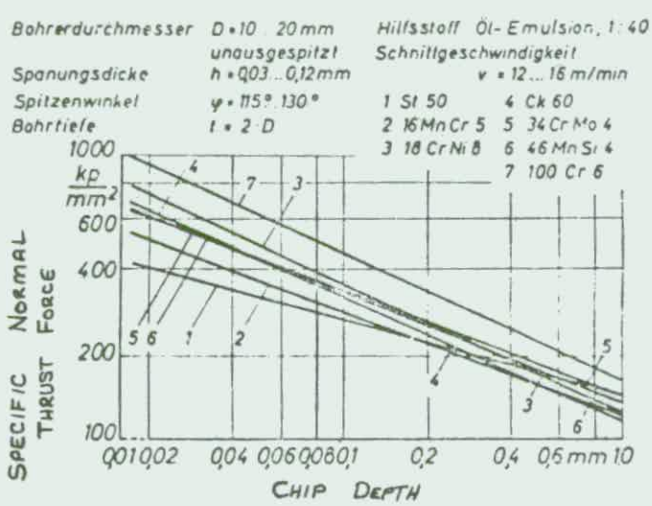


FIG. 7. Specific normal thrust forces depend upon chip depth

1. ANONYMOUS

2. DRILL POINTS AND HOLE SIZE

3. REPRINTED FROM METAL CUTTINGS Published by National Twist Drill & Tool Co., 1964, Vol. 12, No. 3, pp. 1-7

4. A drawing of an extremely dull drill is shown in Fig. 1. The regions of wear are shaded, and indicate the small portion of total drill point surface.

   The effect of six different style points, on 1/4 in. jobbers length drills, on hole oversize is indicated in Fig. 2. No guide bushings were used and since the 1/4 in. jobbers length drill is fairly long and flexible no definite conclusion was reached as to the advantage of a particular style drill point to eliminate bellmouthing.

   The accuracy of the drill point affects the amount of hole oversize. The effect of relative lip height on hole oversize is given in Fig. 3 and the effect of web eccentricity in Fig. 4.

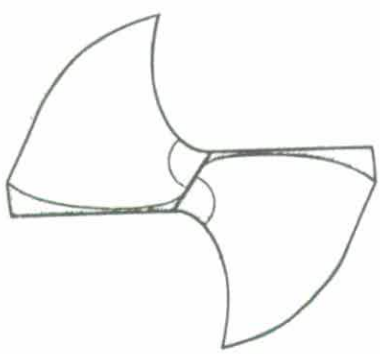


FIG. 1. A worn drill

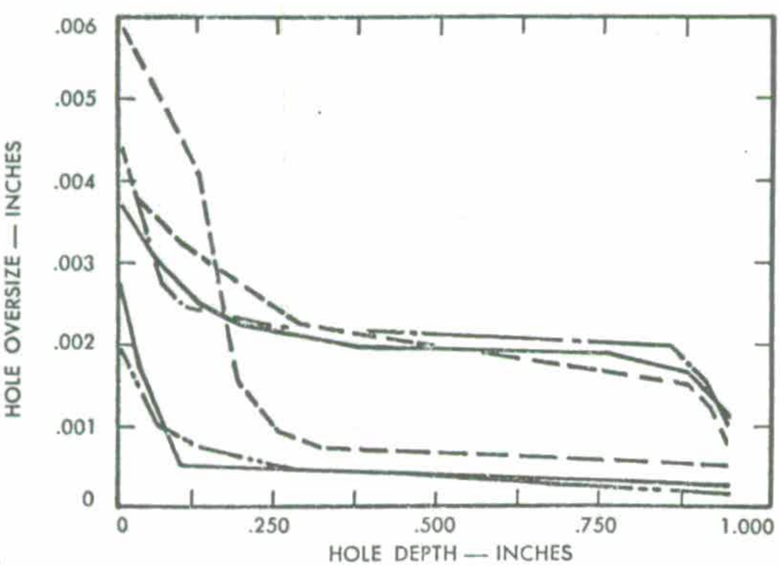


FIG. 2. Oversize vs. hole depth

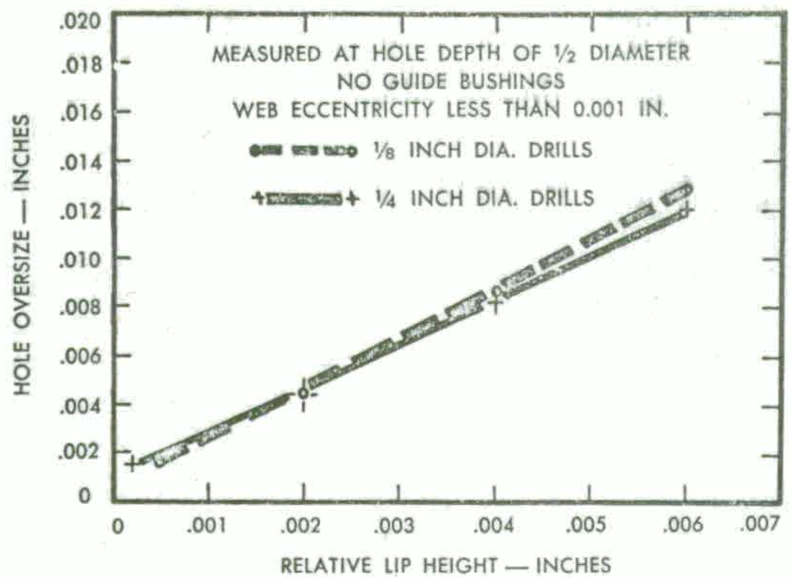


FIG. 3. Effect of relative lip height on hole oversize

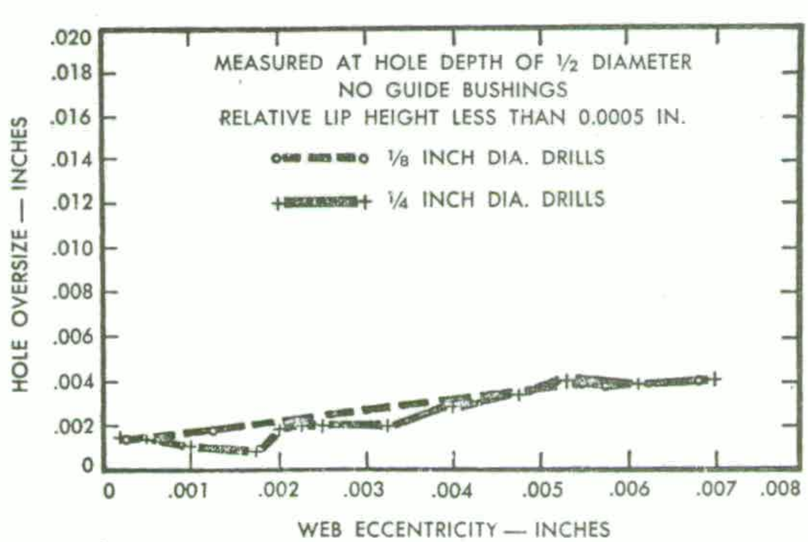


FIG. 4. Effect of web eccentricity on hole oversize

1. BELYAKOVSKI, V. P.

2. DETERMINING THE RAKES OF DRILLS WITH UNDERCUT LIPS

3. RUSSIAN ENGINEERING JOURNAL, 1964, Vol. 44, No. 9, pp. 58-59

4. The author has formulated a method of determining the actual rake angle of drills with undercut lips.

   The actual rake angle is defined as the difference between the static rake in the normal section, Y_n, and the actual position of the cutting plane and its static position, Y_p.

$$Y_a = Y_n - Y_p$$

   The static rake angle of the drill in the normal section, Y_n, is found by measuring the angle between the tangent to the drill cutting edge and the plane parallel to the basic plane of the drill.

   The angle Y_p is found by the expression

$$\tan Y_p = \frac{f \cos \emptyset}{\sqrt{K^2 - f^2}}$$

   where $f = r/R$ is the relative radius of the drill web, r is half the distance between the cutting edges; $K = R_x/R$ is the relative radius of the given point on the cutting edge, R_x is the radius of the investigated point on the cutting edge; and $\emptyset$ is one half the point angle.

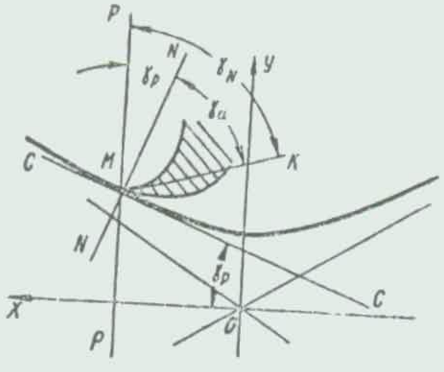


FIG. 1. Special cutting edge geometry

1. ANONYMOUS

2. DRILL MALLEABLE IRON MORE ECONOMICALLY

3. MACHINE AND TOOL BLUE BOOK, 1964, April, pp. 111-113

4. Research performed on pearlitic grades of malleable iron shows that a soluble oil coolant should be used and that the casting skin should be removed for increased drill life.

The tests were conducted using M-10 high speed steel drills with a diameter of 27/64 inch and a 118^{O} point angle. A 1:20 soluble oil cutting fluid was used. The grades of iron tested were: 325.0 (ferritic), 116 BHN, 48004 (pearlitic), 156 BHN, 60003 (pearlitic), 217 BHN, and 80002 (pearlitic), 269 BHN.

The results of varying the cutting speed on drill life for Grades 80002, 60003 and 48004 is shown in Fig. 1. Recommended speeds and feeds for all grades tested are shown in Table 1.

TABLE 1

Grade	Type	Feed (ipr)	Speed (sfm)
32510	Ferritic	.015	300
48004	Pearlitic	.009	225
60003	"	.009	150
80002	"	.009	100

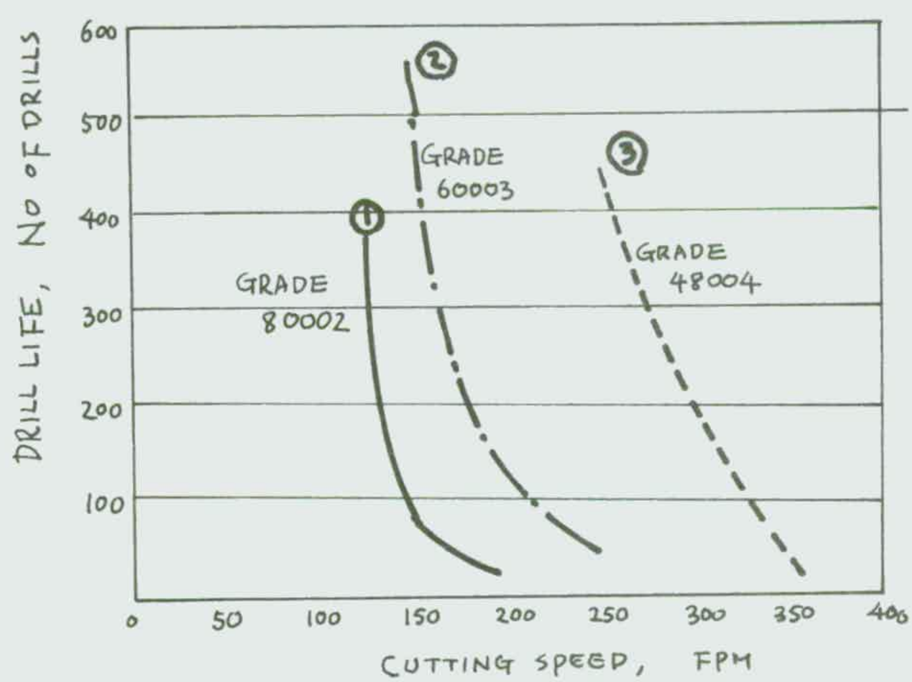


FIG. 1. Drill life vs. drill speed

1. ANONYMOUS

2. DRILLING MALLEABLE IRON

3. THE TOOL AND MANUFACTURING ENGINEER, June 1964, pp. 93-94

4. Drilling tests were conducted on a ferritic malleable iron (ASTM Grade 32510) and three parlitic malleable irons (ASTM Grades 48004, 60003, and 80002). The drill was M-10 HSS, 27/64 in. diameter, chisel edge with a 118 degree point and 7 degree clearance angle. The cutting fluid was 1:20 soluble oil.

   It was determined that cutting speeds can be increased by about 100 percent when the cast surface is removed by machining before drilling. The use of cutting fluid allowed a further increase of 20 to 25 percent increase in cutting speed.

   The effect of various machining variables is shown in Fig. 1.

Effect of Machining Variables on Tool Life When Drilling Malleable Irons.
(a) Grade 32510; (b) Grade 48004; (c) Grade 60003; (d) Grade 80002.

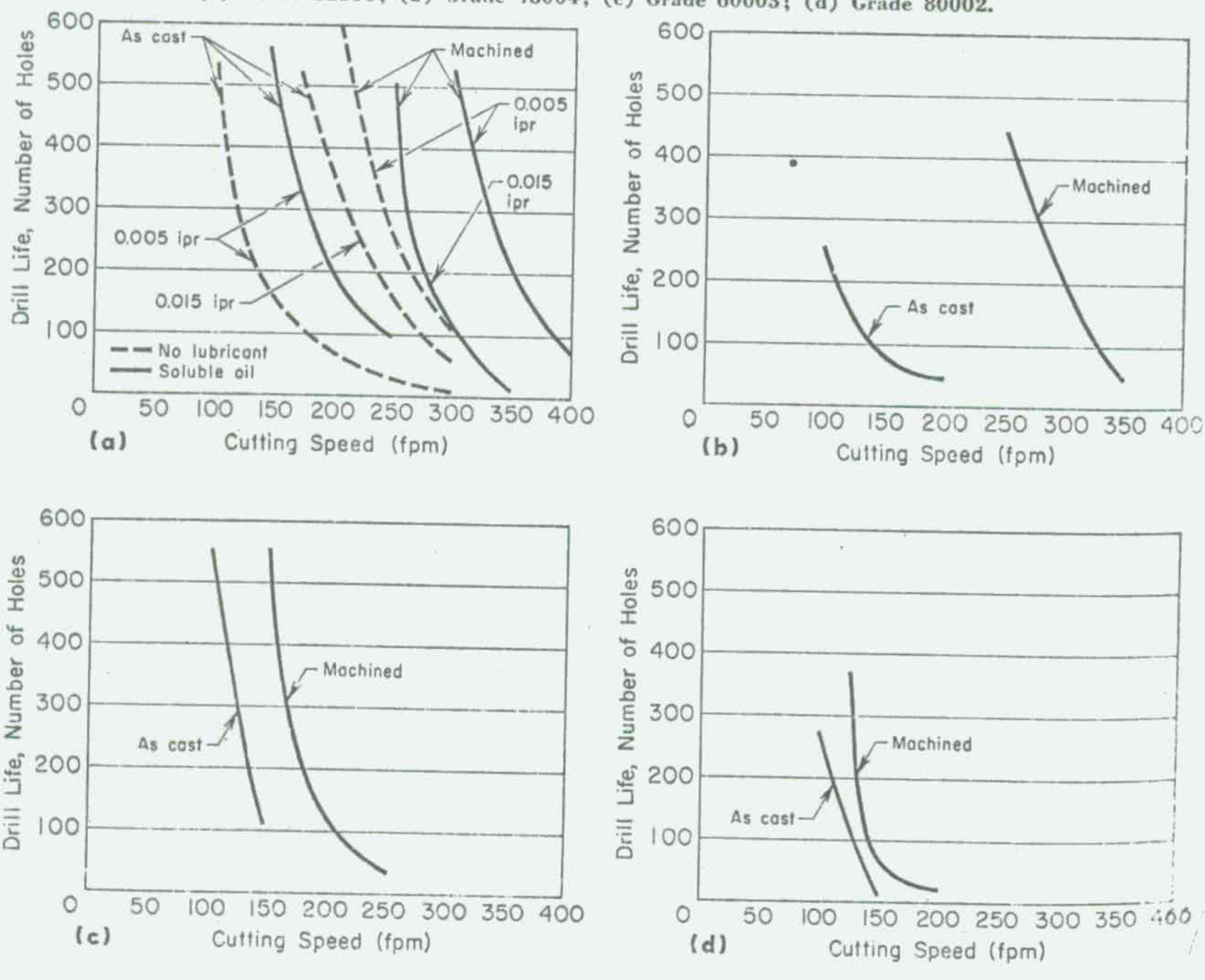


FIG. 1

1. ALEKSEEV, P. G.

2. AN INVESTIGATION OF SOME QUESTIONS ON THE DRILLING PROCESS BY THE MACHINING OF STEEL

3. INVESTIYA VYSSHIKH VCHEBNYKH ZAVEDEN, MASHINOSTROENIYA, 1964, Vol. 11, pp. 154-161

4. By placing standard chromel-alumal thermocouples in grooves between two ground surfaces at a depth of two drill diameters below the top of the workpiece (Fig. 1), Alekseev attempted to establish the temperature distribution on the drill.

The assumption is made that the temperature measured by the thermocouple the instant it is cut is the same temperature as that point on the drill that cuts the thermocouple. Using this method the maximum temperature is indicated to be at the chisel edge decreasing almost linearly to the drill periphery.

Alekseev's investigation indicates the maximum temperature in the drill is at its chisel edge with the temperature decreasing almost linearly to the drill periphery as shown in Fig. 2.

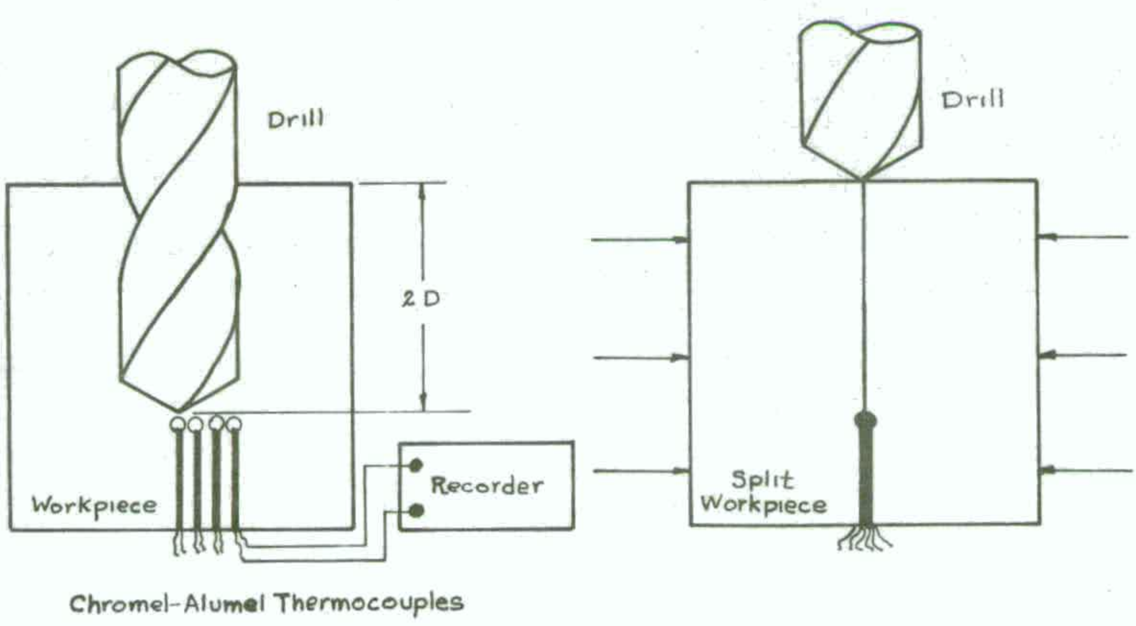


FIG. 1. Thermocouple technique to measure the temperature in drilling

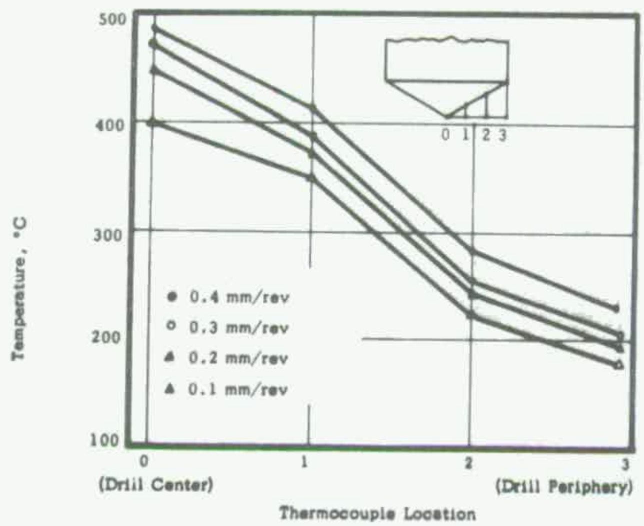


FIG. 2. Drill temperature distribution

1. ZHILIN, V. A.

2. DETERMINING OPTIMUM DRILL OVERHANG WITH CARBIDE TIPPED DRILLS

3. RUSSIAN ENGINEERING JOURNAL, 1964, Vol. 44, No. 2, pp. 49-52

4. Based on the assumption that a lack of rigidity leads to wear of the carbide in the form of chipping the author has derived a relationship for drill length that will give optimum rigidity. For drilling G13L steel with drills tipped with T15K6 carbide the optimum overhang is given as

$$L_{opt} = \frac{\phi_{cr} G J_p}{M_{cr}}$$

ϕ_{cr} = 30' G = shear modulus, J_p = polar moment of inertia and M_{cr} = torque.

It is claimed that with the drill overhang computed by the formula with the angle, ϕ_{cr}, limited to 30' the drill life can be increased 200 to 25%.

1. ANONYMOUS

2. DRILL MAKING GETS A NEW TWIST

3. IRON AGE, 1964, Vol. 194, No. 9, pp. 119

4. Twist drills are produced by a process that combines rolling and forging. This means that the fibrous grain structure is continuous and follows the helix of the flutes. The carbide grains are distributed evenly throughout the metal.

   A blank of HSS is fed into an induction heating coil and heated to 1800°F. The drill is shaped by four precision ground rolls. Two rolls form the flutes and two rolls form the clearances.

   Drills made by this process were tested in annealed 1095 steel (3/8 in. thick) and produced 1350 holes while drills made by other processes averaged 1138 holes.

1. ANONYMOUS

2. FUNDAMENTALS OF HSS CUTTING TOOLS

3. AMERICAN MACHINIST, 1964, Vol. 108, No. 8, pp. 149-156

4. A guide for the proper use of HSS twist drills, including drilling machine condition, cutting fluids, cutting speeds and causes of drilling difficulties.

The drilling machine should be rigid and enough strength and power for the cut. The spindle overhang should be a minimum and the bearings in good condition. Backlash in the feed mechanism should be a minimum to reduce strain on the drill at breakthrough.

The taper of the machine spindle should be free from burrs and dirt.

The surface of the part to be drilled should be free from foreign material.

The main causes of premature drilling are:

1.) Speeds too high for the material being cut.
2.) Feed rate too high
3.) Feed rate too light
4.) Scale or hard spots on the surface being cut
5.) Poor support for tool or work causing chatter
6.) Incorrect drill grind for material being cut
7.) Poor grinding finish

For correct drill sharpening a drill sharpening machine should be used.

Causes of drilling problems, cutting fluid selection and proper cutting speeds are given in Tables 1, 2, and 3 respectively.

Causes of drilling problems

Outer corners break down: Cutting speed too high; Hard spots in material; No cutting compound at drill point; Flutes clogged with chips.

Cutting lips chip: Too much feed; Lip relief too great.

Checks or cracks in cutting lips: Overheated or too quickly cooled while sharpening or drilling.

Chipped margin: Oversize jig bushing.

Drill breaks: Point improperly ground; Feed too heavy; Spring or backlash in drillpress, fixture, or work; Drill is dull; Flutes clogged with chips.

Tang breaks: Imperfect fit between taper shank and socket caused by dirt or chips or by burred or badly worn sockets.

Drill breaks when drilling brass or wood: Wrong type drill; Flutes clogged with chips.

Drill splits up center: Lip relief too small; Too much feed.

Drill will not enter work: Drill is dull; Web too heavy; Lip relief too small

Hole rough: Point improperly ground or dull; No cutting compounds at drill point; Improper cutting compound; Feed too great; Fixture not rigid

Hole oversize: Unequal angle of the cutting edges; Unequal length of the cutting edges; Loose spindle.

Chip shape changes while drilling: Dull drill or cutting lips chipped.

Large chip coming from one flute, small chip from the other: Point improperly ground, one lip doing all the cutting.

TABLE 1

Cutting fluids

Work material	Cutting fluid
Aluminum and its alloys	Soluble oil, kerosene and lard oil compounds, light, non-viscous neutral oil, kerosene and soluble oil mixtures.
Brass	Dry, soluble oil, kerosene and lard oil compounds, light, non-viscous neutral oil.
Copper	Soluble oil, winter-strained lard oil, oleic-acid compounds.
Cast iron	Dry or with a jet of compressed air for cooling.
Malleable iron	Soluble oil, non-viscous neutral oil.
Monel metal	Soluble oil, sulfurized mineral oil.
Stainless steel	Soluble oil, sulfurized mineral oil.
Steel, ordinary	Soluble oil, sulfurized oil, high extreme-pressure-value mineral oil.
Steel, very hard	Soluble oil, sulfurized oil, turpentine.
Wrought iron	Soluble oil, sulfurized oil, mineral-animal oil compound.

TABLE 2

Cutting speeds for HSS drills

Work material	speed (sfpm)	Work material	speed (sfpm)
Aluminum and its alloys	200-300	High-nickel alloys	30-50
Brass and bronze	150-300	Steel, 0.2 to 0.3 carbon	80-110
Die castings, zinc base	300-400	0.4 to 0.5 carbon	70-80
Cast iron, soft	75-125	tool, 1.2 carbon	50-60
medium hard	50-100	forgings	40-50
hard chilled	10-20	alloy, Rh 32-43C	20-30
malleable	80-90	Stainless, free machining	30-80
Magnesium alloys	250-400	work hardening	15-50
		Titanium alloy sheet	50-60

TABLE 3

1. GUEHRING, M.

2. AUSWAHL UND EINSATZ VON BOHRWERKZEUGEN (Selection and Use of Twist Drills)

3. INDUSTRIEBLATT, SONDERDRUCK, 1964, No. 9, pp. 1-11

4. The reason why drill life varies much more than other metal cutting processes can be explained by the following main factors:

   a) Twist drill
   b) Workpiece
   c) Machine tools and fixtures

   The material that was used for the twist drills was high speed steel. It was found that the chemical content of the raw material and the microstructure affect drill life. As is shown in Fig. 1, the drill manufacture made it possible to increase drill life by a special heat treatment which formed a small microscopic hard layer without reducing the modulus of elasticity of the drills.

   The essential factor affecting drill force and drill life was the pointing of the chisel edge. Symmetrically ground drills obtained increased drill life.

   Hole form, depth of hole and location of the hole in the workpiece, shown in Fig. 2, also affect drill life.

   The wear on the drill always begins on the workpiece that is most stressed during drilling. Chisel edge wear is caused by higher hardness of the workpiece. Rapid wear on the corner is a sign that the drilling speed is too high. The wear on the margin occurs if the material tends to build up by welding because of higher friction and temperature on the side edge.

   It is significant, through changing the cutting speed and feed rate, to determine optimum drilling conditions. Often the drill life will be increased if drilling speed is reduced while the feed rate is increased. At the best drilling conditions, it can be assumed that the wear on the cutting edges develops uniformly.

   It is observed when drilling deep holes that the chip flow through the flutes obtains large friction resistance. Therefore, it is difficult for the coolant to act at the chisel edge.

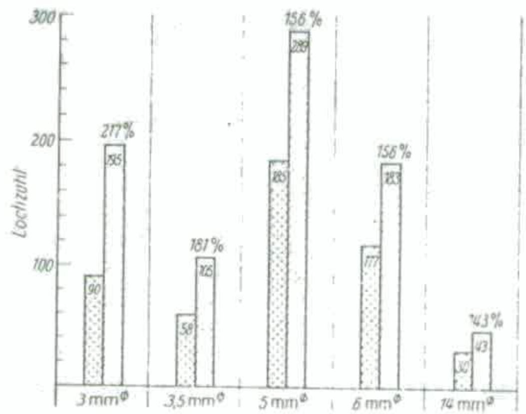


FIG. 1. Increased drill life by special point grinding

FIG. 2. Examples of effects of form of holes

1. ANONYMOUS

2. FEED AND SPEED SELECTION - FEED IS THE KEY

3. Reprinted from METAL CUTTING, Published by National Twist Drill and Tool Co., 1965, Vol. 13, No. 1, pp. 1-7

4. In tool life tests it is found that by increasing the speed or feed, the tool life will decrease. An increase in speed will give a greater decrease in tool life than a corresponding increase in feed. Figure 1 indicates the effect on tool life of the feed when the speed and feed are adjusted to give a constant production rate.

Power is proportional to the cutting force times speed. The cutting force is relatively unaffected by cutting speed although it generally varies with about the 0.8 power of feed.

Since the cutting forces increase with feed the strength of the cutting edge of the tool and the strength of the tool must be considered as the feed is increased.

Large twist drills (above 5/8 in. dia.) tend to have the point chip when light feeds are used. This chipping generally occurs before the point is buried in the workpiece and is related to the instability of the chisel edge and the flexibility of the drill.

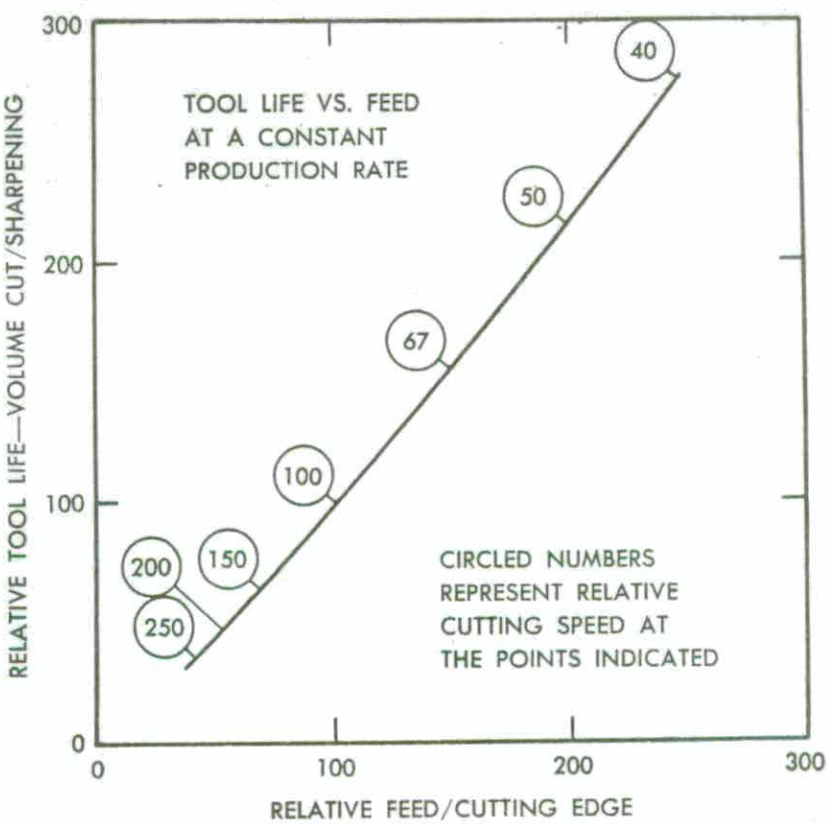


FIG. 1. Effect of feed upon tool life

1. ANONYMOUS

2. ESTIMATING TORQUE AND THRUST REQUIREMENTS FOR ROTARY END CUTTING TOOLS

3. REPRINTED FROM METAL CUTTINGS, Published by National Twist Drill & Tool Co., 1965, Vol. 13, No. 3, pp. 1-11

4. The formulas developed by M. C. Shaw and C. J. Oxford, Jr. in 1955 for predicting the torque and thrust in drilling have been reduced to a simplified form. The simplified equations are:

$$M = Kf^{0.8}d^{1.8}\ A$$
$$T = 2Kf^{0.8}\ d^{0.8}\ B + Kd^{2}\ E$$

If the drill diameter, web thickness, feed rate and work material are known, it is only necessary to look up the values for K, $f^{0.8}$, $d^{0.8}$, $d^{1.8}$, d^{2}, A, B and E from Tables 1-3 to determine the torque and thrust.

For other than regular drills the chisel edge length is based on the web thickness at the point and the diameter used is the largest diameter of the tool in contact with the workpiece.

For enlarging holes the formulas become:

$$M = KRf^{0.8}\ d^{1.8}\ \left[\frac{1 - \left(\frac{c}{d}\right)^{2}}{\left(1 + \frac{c}{d}\right)^{.2}}\right]$$

$$T = 2KRf^{0.8}\ d^{0.8}\ \left[\frac{1 - \frac{c}{d}}{\left(1 + \frac{c}{d}\right)^{.2}}\right]$$

M = Torque (in.-lbs.)
T = Thrust (lbs)
K = Work material constant
R = Correction factor for number of flutes (Table 4)
f = Feed (ipr)
d = Largest tool diameter in contact with workpiece (in.)
c = Existing hole diameter (in.)

Torque and Thrust Terms Based Upon Feed, f

Feed, ipr f	$f^{0.8}$
.0005	.0025
.001	.004
.002	.007
.003	.010
.004	.012
.005	.014
.006	.017
.008	.020
.010	.025
.012	.030
.015	.035
.020	.045
.025	.055
.030	.060

TABLE 1

Torque and Thrust Terms Based Upon Diameter, d

Diam. Inches d	$d^{0.8}$	$d^{1.8}$	d^2
1/16 .063	.110	.007	.004
.094	.150	.014	.009
1/8 .125	.190	.025	.016
.156	.225	.035	.025
3/16 .188	.260	.050	.035
.218	.295	.065	.050
1/4 .250	.330	.095	.065
.281	.365	.105	.080
5/16 .313	.395	.125	.105
.344	.425	.145	.120
3/8 .375	.455	.170	.140
.438	.515	.225	.190
1/2 .500	.575	.285	.250
.563	.630	.375	.315
5/8 .625	.685	.430	.390
.688	.740	.510	.470
3/4 .750	.795	.595	.565
.875	.900	.785	.765
1 1.000	1.000	1.000	1.000
1.125	1.010	1.235	1.270
1.250	1.195	1.495	1.565
1.375	1.290	1.775	1.890
1.500	1.385	2.075	2.250
1.625	1.475	2.400	2.640
1.750	1.565	2.740	3.060
1.875	1.655	3.100	3.520
2.000	1.740	3.480	4.000

TABLE 2

Work Material Constants for Calculating Torque and Thrust

Work Material	K
Steel, 200 BHN	24,000
Steel, 300 BHN	31,000
Steel, 400 BHN	34,000
Most Aluminum Alloys	7,000
Most Magnesium Alloys	4,000
Most Brasses	14,000
Leaded Brass	7,000

TABLE 3

Torque and Thrust Correction Factor Based Upon Number of Flutes

Number of Flutes	Factor R
1	.87
2	1.00
3	1.09
4	1.15
5	1.20
6	1.25
8	1.32
10	1.38
12	1.44
14	1.48
16	1.52
20	1.60

TABLE 4

1. BAKER, ALAN

2. STANDARDIZED NC CUTTING TOOLS

3. AMERICAN MACHINIST, June 21, 1965, pp. 115-118

4. The importance of accurate drills for use in NC machines is stressed. There is no advantage to having a table that can be positioned within 0.0005 in. when the drill in the spindle has a 0.002 in. runout and the drill lips are 0.005 in. eccentric.

When using drill bushings, the accuracy of the drill is not important while in NC machines the location, size and quality of the hole is determined by the drill itself. To insure that the drill is held concentrically, collets are recommended over chucks. Average lip concentricity of new drills is shown in Table 1 with suggested maximum recommended lip eccentricity shown in Table 2.

The shorter the drill the greater the torsional rigidity and the better the tool life and hole quality. This can be achieved by using screw machine length drills, shortening existing drills or by using collets that grip on the drill flute. If an existing drill is made shorter it will probably be necessary to thin the drill web at the point.

When using center drills, the countersink portion should be 0.003 to 0.006 in. larger in diameter than the finished hole size.

The identification of the drill, when on the shank, should be by chemical etching and not by metal stamp. The stamp will cause the metal around the letters to be raised and cause the drill to be located eccentrically.

Table 1. Average new drill lip eccentricity

Diameter	Max lip eccentricity
Up to 0.093 in.	0.001 in.
0.093-0.136	0.002
0.140-0.221	0.003
0.228-0.500	0.004
0.515-1.000	0.005

Table 2. Suggested lip concentricity for NC

Diameter	Max lip eccentricity
Up to 0.093 in.	0.0005 in.
0.093-0.136	0.0008
0.140-0.221	0.0015
0.228-0.500	0.0020
0.515-1.000	0.0030

1. ANONYMOUS

2. DRILLING TITANIUM ALLOYS 1, 2

3. AMERICAN MACHINIST, Dec., 1965, pp. 87-88

4. When drilling titanium feathered or discolored chips indicate that the drill is dull. The chips also tend to clog the flutes of a dull drill due to the lip and margin becoming smeared with titanium.

Short length drills with a crankshaft point are recommended. Using the recommended feeds and speeds of Table 1 and 2 with HSS drills the tool life should be around 75 holes.

TABLE 1.

Drilling recommendations

Tool geometry—stub length drill, PA 118°, CL 7°, PG: crankshaft
Cutting fluid—highly chlorinated oil or sulpho-chlorinated oil

Material	Condition	BHN	Speed fpm	Feed, ipr Hole diameter, in. ⅛	¼	½	¾	1	1½	2	3
Commercially pure titanium											
99.5	Annealed Y. S. - 20,000-30,000	110-170	100	0.0005	0.002	0.006	0.007	0.008	0.010	0.013	0.015
99.2 99.0 0.15 to .20 Pd	Annealed Y. S. - 45,000-60,000	140-200	80	0.0008	0.003	0.006	0.007	0.008	0.010	0.013	0.015
99.0 98.9	Annealed Y. S. - 60,000-85,000	200-275	50	0.002	0.005	0.006	0.007	0.008	0.010	0.013	0.015
Alpha and alpha-beta alloys											
2.5Al-16V	Solution treated Y. S. - 45,000-60,000	150,200	70	0.002	0.005	0.006	0.008	0.009	0.010	0.012	0.013
3Al-2.5V	Annealed Y. S. - 80,000-90,000	200-260	50	0.002	0.005	0.006	0.008	0.009	0.010	0.012	0.013

TABLE 2.

Drilling recommendations

Cutting fluid—highly chlorinated oil or sulpho-chlorinated oil
Tool geometry—stub length drill, PA 118°, CL 7°, PG: crankshaft

Material	Condition	BHN	Speed fpm	Feed, ipr Hole diameter, in. ⅛	¼	½	¾	1	1½	2	3
Alpha and alpha-beta alloys (continued)											
2Fe-2Cr-2Mo 5Al-2.5Sn 5Al-2.5Sn (low O) 7Al-2Cb-1Ta 4Al-3Mo-1V 5Al-5Sn-5Zr	Annealed Y. S. - 115,000-125,000	300-340	40	0.002	0.005	0.006	0.007	0.008	0.010	0.011	0.012
7Al-12Zr 6Al-4V 4Al-4Mn 8Mn	Annealed Y. S. - 125,000-135,000	310-350	30	0.002	0.005	0.006	0.007	0.008	0.009	0.010	0.011
7Al-4Mo 8Al-1Mo-1V 5Al-1.25Fe-2.75Cr 5Al-1.5Fe-1.4Cr-1.2Mo 6Al-6V-2Sn-1(Fe, Cu)	Annealed Y. S. - 140,000-150,000	320-370	20	0.002	0.005	0.006	0.007	0.008	0.009	0.010	0.011
1Al-8V-5Fe	Annealed Y. S. - 160,000-180,000	320-380	15	0.002	0.004	0.005	0.006	0.007	0.008	0.009	0.010
6Al-4V 4Al-4Mn 2.5Al-16V	Solution treated & aged Y. S. - 143,000-165,000	350-400	25	0.001	0.002	0.004	0.005	0.006	0.007	0.008	0.008
2Fe-2Cr-2Mo 5Al-1.25Fe-2.75Cr 6Al-6V-2Sn-1(Fe, Cu) 7Al-4Mo 5Al-1.5Fe-1.4Cr-1.2Mo 4Al-3Mo-1V	Solution treated & aged Y. S. - 165,000-185,000	375-420	20	0.001	0.002	0.003	0.004	0.004	0.005	0.005	0.005
1Al-8V-5Fe	Solution treated & aged Y. S. - 175,000-245,000	375-440	15	0.0005	0.001	0.0015	0.0015	0.002	0.002	0.003	0.004
Beta alloys											
3Al-13V-11Cr	Solution treated Y. S. - 135,000-145,000	310-350	20	0.001	0.003	0.004	0.005	0.006	0.007	0.008	0.009
3Al-13V-11Cr	Solution treated & aged Y. S. 175,000-245,000	375-440	15	0.0005	0.001	0.0015	0.0015	0.002	0.002	0.003	0.004

1. ANONYMOUS

2. DRILLING AND REAMING MARTENSITIC STEEL

3. MACHINERY, 1965, Vol. 71, No. 12, pp. 132-134

4. When drilling D6AC steel with strengths in the range of 220,000 to 240,000 psi and a hardness of R_C 46 to 49 Cobalt type high speed steel drills were used.

   Oil hole type drills were used when the drill diameter was 5/16 inch or larger and solid drills with flood cooling for drills smaller than 5/16 in. diameter.

   The drills had heavy webs with flute lengths kept at a minimum for maximum rigidity.

   The web was thinned to 0.005 to 0.015 inch at the chisel edge and the relative lip height was held within 0.0005 in. The cutting surfaces had a finish of 20 micro inches.

   Under ideal production conditions the drills can cut a thickness equal to 20 times their diameter before regrinding.

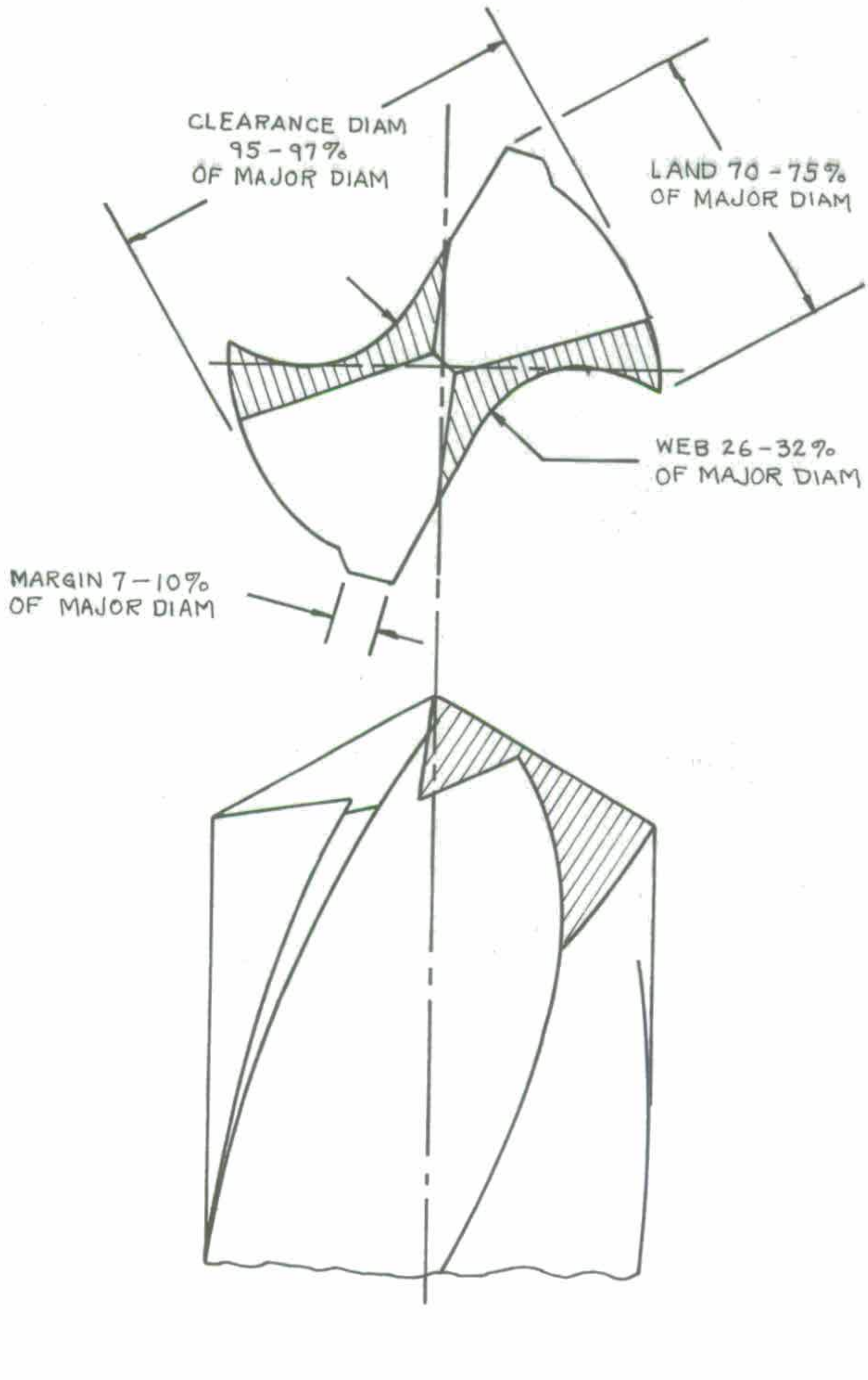


FIG. 1. Heavy duty drill configuration

1. HILL, J. M.

2. COMPUTERIZED TORQUE CONTROL EXTENDS DRILL LIFE AND BOOSTS PRODUCTIVITY

3. MACHINERY, 1965, Vol. 71, No. 5, pp. 128-129

4. When drilling 3/52 in. diameter holes 2.875 in. deep in SAE 4340 steel bar stock having a hardness of 28 to 35 Rockwell C, drill life has more than doubled by using computerized torque control units.

   The computer mounted on each drill is set so that optimum torque is maintained for the particular material being drilled. This setting is made so that the drill will remove the most metal with a minimum of heat generation.

   Maximum speed, horsepower and torque are limited by dial settings on the computer console.

1. LEVIN, R. S.

2. MICRODRILLING: PRINCIPLES AND PRACTICES

3. MACHINERY, 1965, Vol. 72, No. 2, pp. 147-151

4. Microdrilling consists of drilling close-tolerance holes with diameters ranging from 1/8 inch down to 0.0006 inch.

   Hole straightness is affected by several factors. The following are recommended procedures:

   The workpiece and drill are rotated in opposite directions. Workpiece speeds of 100-300 rpm and drill speeds of 200 to 4000 rpm.

   The drill should contact the work surface at an angle normal to the surface.

   Drilling pressure should not exceed allowable limits.

   The proper drill speed and feed is determined by observing the chip shape through a microscope. The chip shape is characteristic of the material and the drill.

   Spindle runout should not exceed 0.000050 inch, TIR. The spindle, collet and drawbar should be kept clean of chips and dirst of any size.

   Collets should be checked in the spindle for excessive runout.

   Drills should be selected so that variations in drill material, hardness, flute length, flute style and point configurations are kept at a minimum.

1. ANONYMOUS

2. FOUR-LAND TWIST DRILL CUTS AT DOUBLE SPEED

3. MACHINERY, 1965, Vol. 72, No. 1, pp. 352-354

4. A twist drill design that embodies four lands is reported to have a tool life of 3-4 times that of conventional drills when operated under identical conditions. For the same tool life the cutting speed of the four land drill can be increased 1.5 to 2 times.

   The total width of both lands of new drill are 1 to 1.5 times the land width of the standard drill.

   The chamber behind the additional land has a width of 0.1 to 0.13 times the drill diameter. The core diameter has been increased to 0.19 to 0.22 times the drill diameter. This was necessary to compensate for the loss in strength caused by two additional flutes.

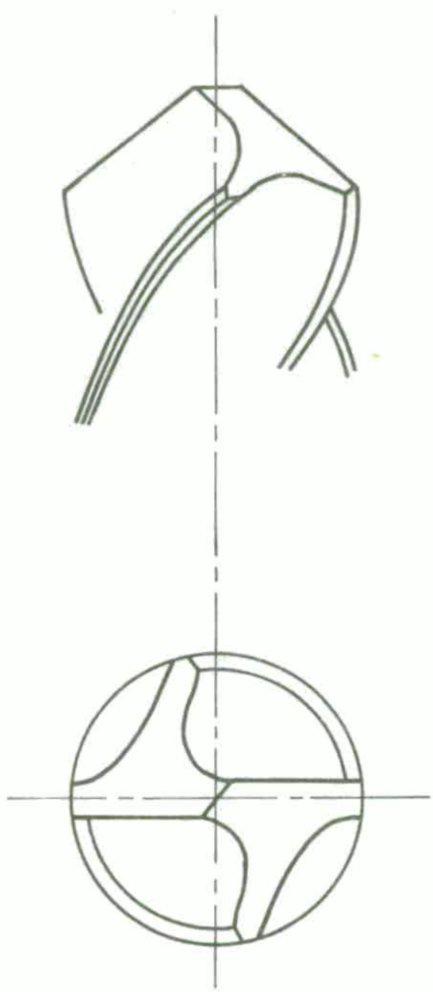


FIG. 1. Four land twist drill

1. KRYUCHKOV, N. K.

2. A SUB-LAND TYPE TWIST DRILL

3. MACHINES & TOOLING, Vol. 36, No. 3, pp. 34-35

4. The sub-land drill, Fig. 1, has a main land B and an auxiliary land C which is 30 to 40% less than the main land. The total width of the two lands is approximately equal to the land width of an ordinary twist drill. The depth and width of the groove E which separates the two lands depends on the drill diameter.

   For 5 to 12 mm diameter drills the groove E is a circular arc of radius

$$R = \frac{a^2 + 4h^2}{h}$$

   where a is the groove width and h is the depth. It has been established that h = (0.20 to 0.24) d where d is the drill diameter. The groove width a is found by

$$a = b - (f_1 + f_2 + f_3)$$

   where b is the width across the lands, f_1 is the width of the main land and f_3 is the width of the land additional to the auxiliary land. The web diameter for a sub-land drill is greater than that for a standard drill.

   The recommended helix angle for 3 to 5 mm diameter drills is 25 to 35 degrees and for 5 to 12 mm diameter drills the helix angle should be 35 to 40 degrees.

   Due to the increased flute width there is a better chip flow. When using a flood coolant the coolant can flow down the groove and the flutes for better cooling.

   Tests were conducted with 3.5, 8 and 10.5 mm diameter R18HSS drills. The work material was 0.4-0.5 carbon steel using a 1:20 water soluble coolant. The holes were drilled to a depth of six drill diameters.

   The effect of cutting speed, feed rate and drill diameter for both conventional twist drills (Curve 1) and sub-land drills (Curve 2) is shown in Figs. 2, 3, and 4 respectively.

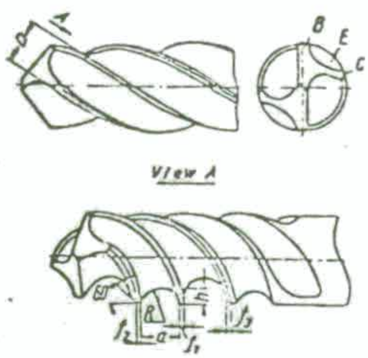


FIG. 1. Sub-land drill

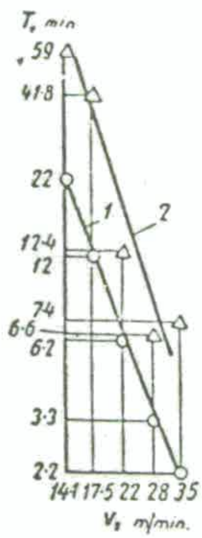


FIG. 2. Drill life vs. cutting speed

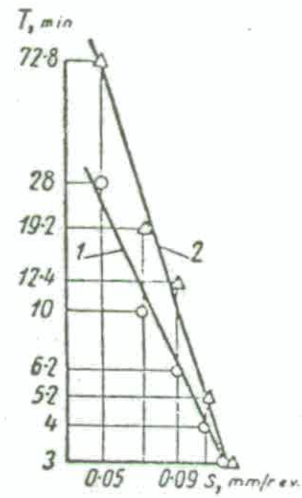


FIG. 3. Drill life vs. feed rate

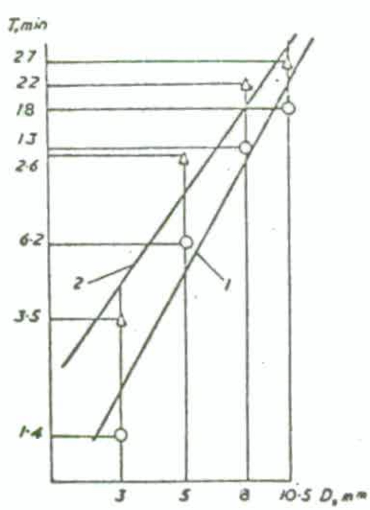


FIG. 4. Drill life vs. drill dia.

1. PAL, A. K.; BHATTACHARYYA, A. and SEN, G. C.

2. INVESTIGATION OF THE TORQUE IN DRILLING DUCTILE MATERIALS

3. INTERNATIONAL JOURNAL OF MTDR, 1965, Vol. 4, No. 4, pp. 205-221

4. A relationship has been derived to theoretically determine the torque in drilling ductile material by considering the initial properties of the material, drill geometry and cutting conditions.

The relationship is

$$T = (r_2^2 - r_1^1) \left\{ 0.74 \sigma_u \, 6^{0.6\Delta} S \left(0.585 + \frac{7}{r_m^{0.7} S^{0.112}}\right) + \frac{F}{\sin \rho} \right\} - 0.0109 \, \sigma_u \, 6^{0.6\Delta} S (r_2^3 - r_1^3)$$

where

r_2 = outside radius of the drill,
r_1 = radius of pilot hole
σ_u = ultimate tensile strength
Δ = percent elongation
F = friction force on drill flank
ρ = ½ of the point angle
S = feed rate

The equation was derived from a more general equation in which $T = \int_{r_1}^{r_2} S r \tau_s \left[A - B\alpha_e + \zeta \right] dr + T_F$. In this relationship the shear stress, τ_s , was defined as $\tau_s = 0.74 \, \sigma_u^{0.6\Delta}$, a relationship derived by Abuladze. The relationship of effective rake angle α_e, and chip thickness coefficient, ζ, is given as $A - B\alpha_e + \zeta$ where ζ is further defined as $\zeta = \frac{14}{r_m^{0.7} S^{0.112}}$
r_m - mean radius of the drill.

A comparison of the theoretical and experimental values show close agreement except near the chisel edge. As the diameter of the pilot hole decreased the torque increased until the pilot hole size approaches the chisel edge region where the torque leveled off. This is shown in Fig. 2.

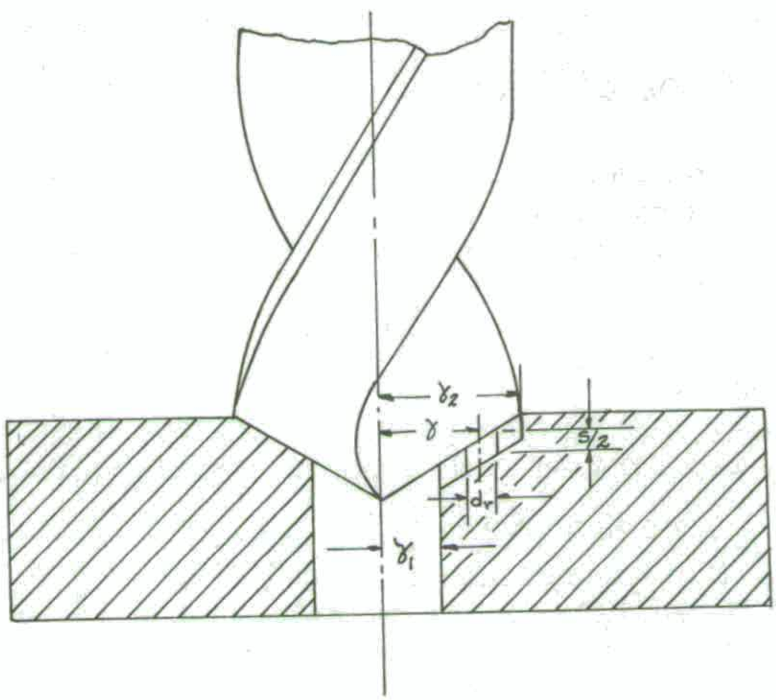


FIG. 1. Drill cutting process

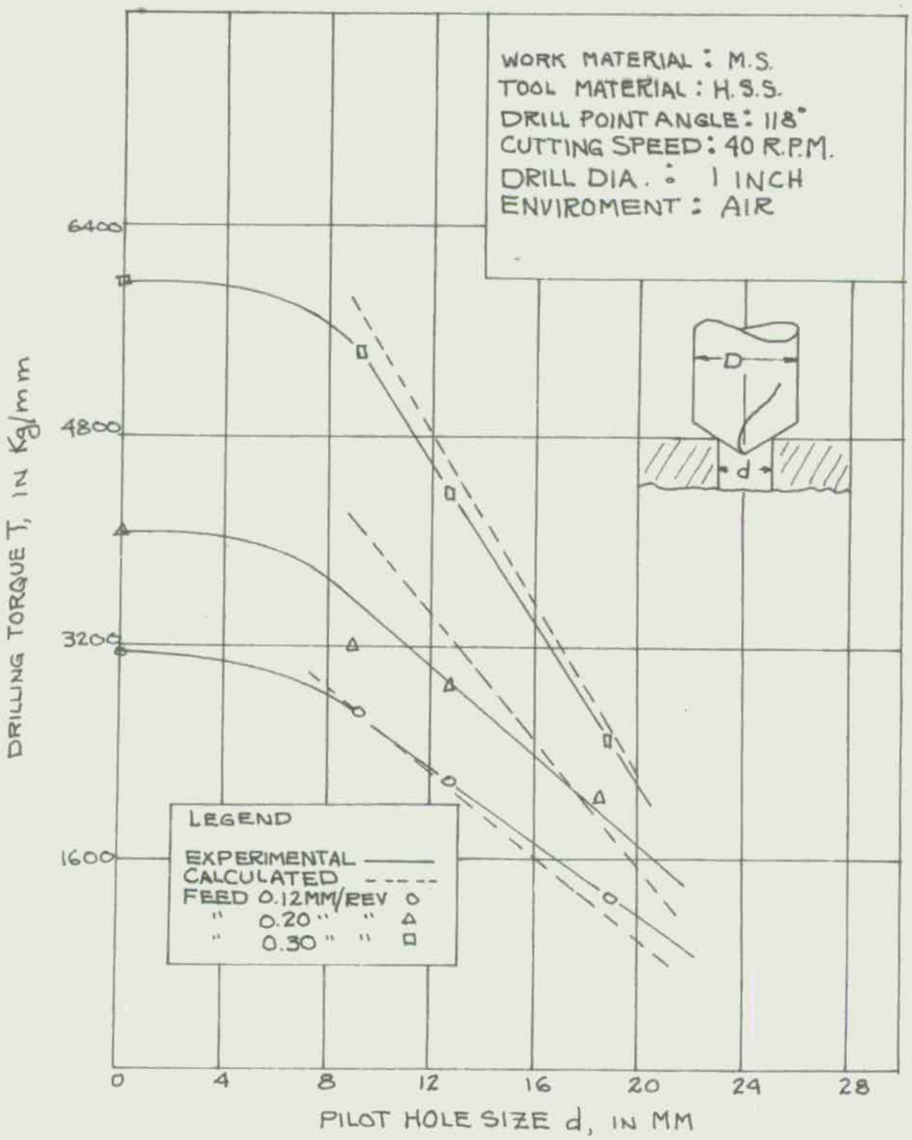


FIG. 2. Comparison of theoretical and experimental torque with varying pilot hole size

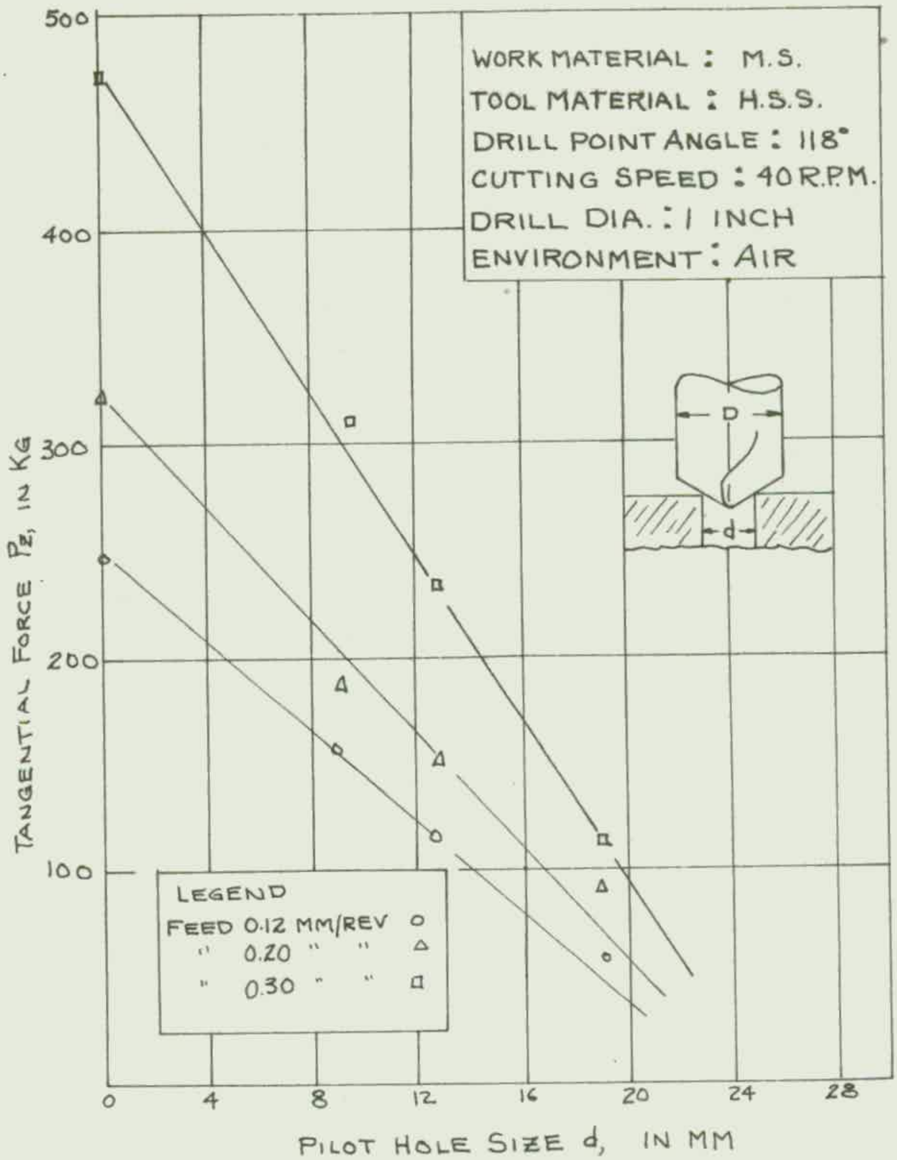


FIG. 3. Influence of pilot hole size on tangential force

1. CANNON, R.

2. DRILLING LAMINATES FOR PRINTED CIRCUITS

3. THE TOOL AND MANUFACTURING ENGINEER, March 1965, pp. 63-64

4. The drill geometry is an important factor when drilling reinforced plastic laminates. A point angle of 118 degrees provides best results. For satisfactory plating, holes must be within size and location tolerance and straight and smooth enough for plating. A heel clearance of 12 to 15 degrees gives the best combination of drilling ease and stability.

A flute cross-sectional area that is 70 percent of the whole drill, Fig. 1, provides sufficient area to carry away the chips. The flutes are also polished or chrome plated. The drill margin is kept narrow, under 5 degrees. A table showing the time required to drill 1000 holes, 0.625 in. diameter through 0.100 in. laminate by various methods is also shown in Fig. 2.

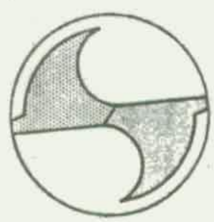


FIG. 1

Times to Drill 1000 Holes 0.0625-inch Diam Through 0.100-inch Laminate

Machine (Type and Speed)	High Speed Steel Drills Speed (rpm)	Time (hrs)	Carbide Drills Speed (rpm)	Time (hrs)
Single Spindle (15,000 rpm max)	10,000	0.410	15,000	0.372
Single Spindle (9,000 rpm max)	9,000	0.422	9,000	0.422
Single Spindle Drilling from Bottom (30,000 rpm max)	10,000	0.245	30,000	0.170
3-Spindle Tape Programmed, Automatic Cycle (30,000 rpm max)	10,000	0.172	30,000	0.147

FIG. 2

1. PATEL, K. N.

2. DRILLING OF BERYLLIUM COPPER ALLOYS

3. ASTME PAPER NO. MR65-109, 1965

4. The research was concerned with an evaluation of the drilling operation of Berylco 25 alloy which has a tensile strength of 170,000 psi and a hardness of 401 to 60 Rockwell C.

   For optimal results in drilling deep holes the following conditions are recommended:

   1. Drilling speeds - 70 - 90 sfpm
   2. Drilling feeds - .001 - .004 ipr
   3. Drill geometry - 118 or 130 degree point angle double relief angles on drill lips
   4. Cutting fluids - flood coolant

1. KIRSCHBAUM, R. A.

2. DRILLING 18% NICKEL MARAGING STEEL

3. ASTME TECHNICAL PAPER NO. MR65-617, 1965, pp. 1-15

4. The drills used on this test were 1/2 in. diameter T-15 with the webs thinned to .070 in. with a standard point geometry. A water soluble oil coolant (1:20) was used as a flood coolant.

   The best tool was obtained at a speed of 95 fpm with a feed rate of 0.0062 ipr. Lower feed rates at the same speed did not produce as long a tool life.

   An excessive burr was left on the through side of all the holes. The burrs became larger as the speeds and feeds were increased.

   High alloy, cobalt-type drills with standard or heavier than standard web thickness should be used with a chisel point. Stub length drills are also recommended.

1. VENKATARAMAN, R., LAMBLE, J. H., KOENIGSBERGER

2. ANALYSIS AND PERFORMANCE TESTING OF A DYNAMOMETER FOR USE IN DRILLING AND ALLIED PROCESSES

3. INT. J. MACH. TOOL DES. RES., 1965, Vol. 5, No. 4, pp. 233-261

4. The design of a dynamometer that is capable of measuring thrust, torque, and radial forces simultaneously is discussed.

   The basic shape of the dynamometer is that of a wheel with four spokes attached to a center hub that is the workpiece holder. Strain gages are suitably attached to the spokes to measure the torque, thrust and radial forces.

   The dynamometer is capable of measuring thrust from 20 to 1500 lb. and torque from 15 to 2000 ft-lb.

   A schematic of the basic dynamometer shape is shown in Figs. 1 and 2 which give the approximate strain gage location and the strains associated with each type of load.

   The dynamometer was tested under dynamic conditions and was found to have a flat response to over 150 cps.

   Cutting tests were conducted and the results compare favorably with previous tests.

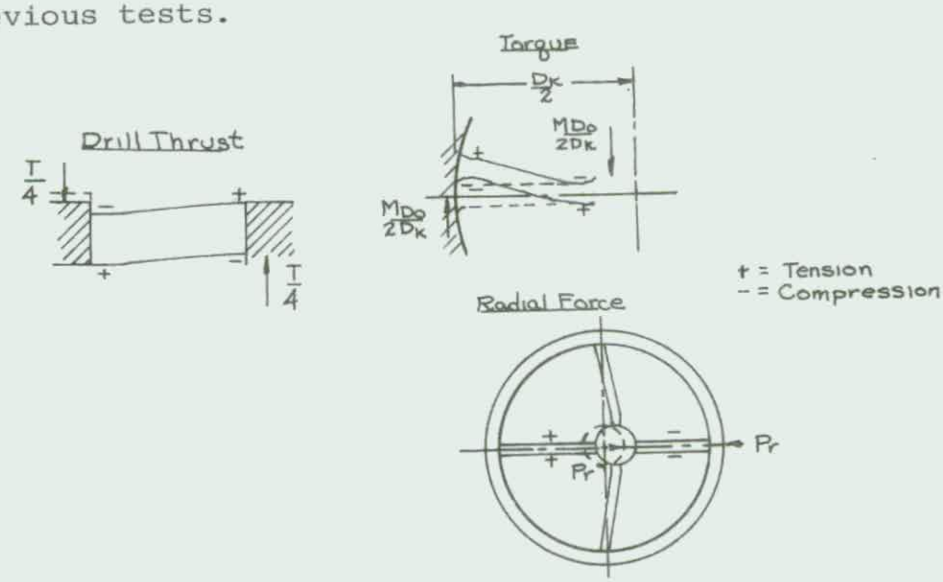


FIG. 1. Deformations associated with each type of load

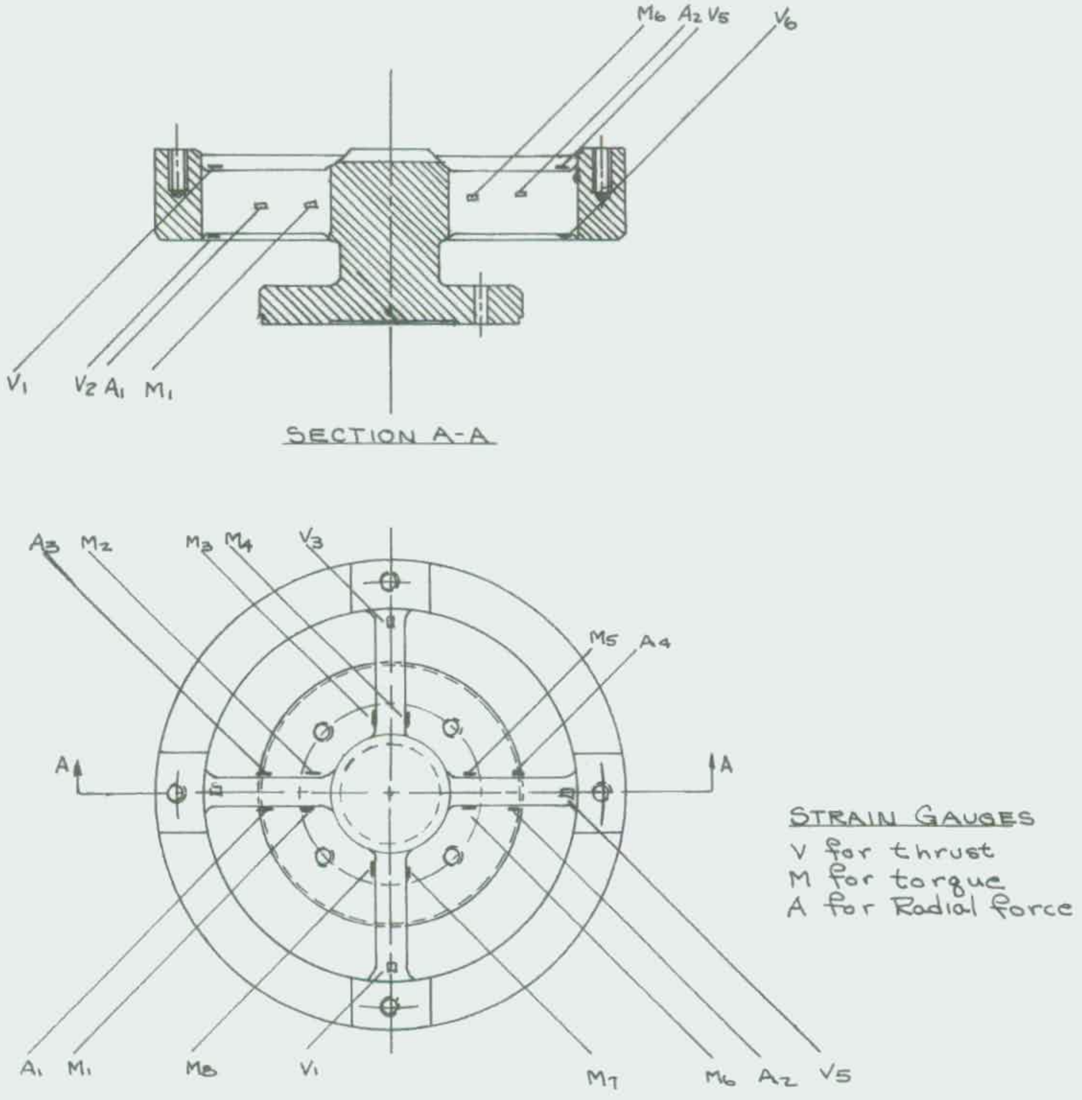


FIG. 2. Dynamometer showing strain gage location for each type of force measured

1. TILLOTSON, R. N.

2. DRILL BIT DESIGN ASSURES CLEAN HOLES IN LAMINATED MATERIALS

3. NASA TECH BRIEF 65-10386, 1965, pp. 1

4. In order to eliminate delamination due to generated heat and tearing of the material at the ends of the holes, a new drill bit, Fig. 1, was designed.

   The drill bit is made by grinding hollows on each side of the drill body so that the narrowest part is in the center and the widest at the periphery. A diagonal line drawn through a cross-section passes through the drill center and represents zero degrees radial rake. The radius of the hollow ground portion is such that the angle between the zero degree radial rake line and a tangent to the bit at the corner form a positive rake angle of 1 to 15 degrees. The radial rake decreases to a negative value at point C.

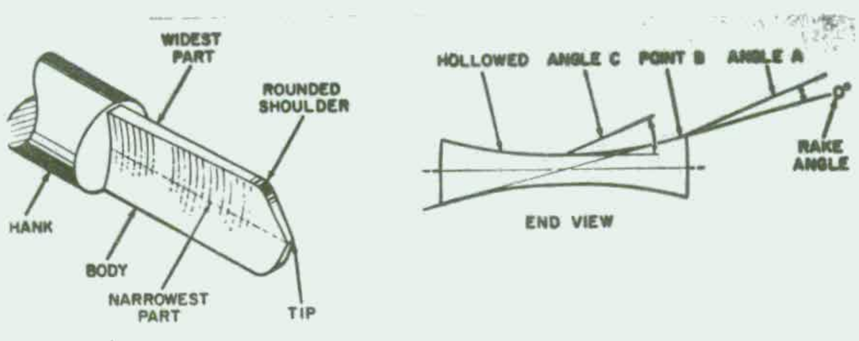


FIG. 1. New designed drill bit

1. RICH. E. A.

2. PULSING COOLANT SPEEDS DRILLING

3. AMERICAN MACHINIST, April 25, 1966, pp. 86-89

4. An increase in penetration rates has been obtained by using oil hole drills in combination with a pulsing coolant system. The system improves drill life, Figs. 1 and 2, and improves the surface finish of the hole. It also eliminates the necessity of woodpeckering to remove chips and cool the tool.

   The system works best when high feed rates are used which produce thick chips which are easily broken into short segments.

   Various cutting fluids have been used and it has been found that the type has little effect on the results obtained.

   The speeds and feeds used when drilling dry or with flood coolant do not apply for pulsed pressure coolant systems.

   Under normal drilling operation, the pressure of the fluid leaving the end of the drill seldom exceeds 50-60 psi.

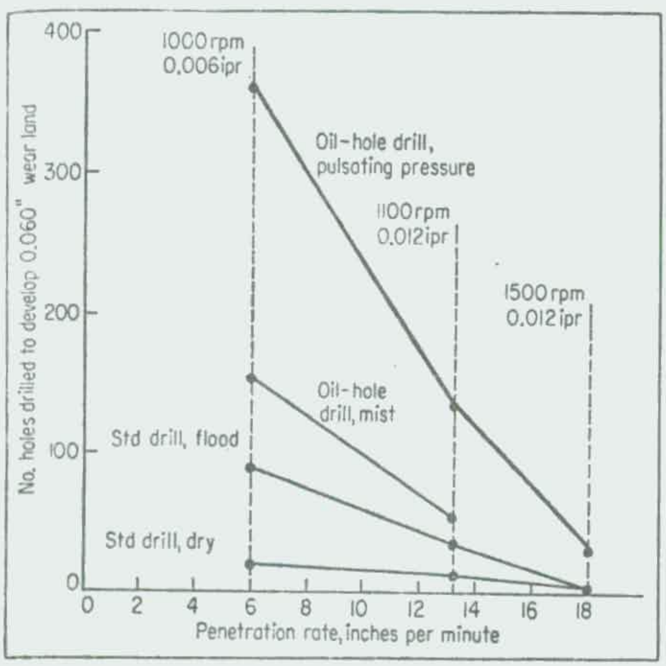


FIG. 1. Effect of coolant system upon drill life

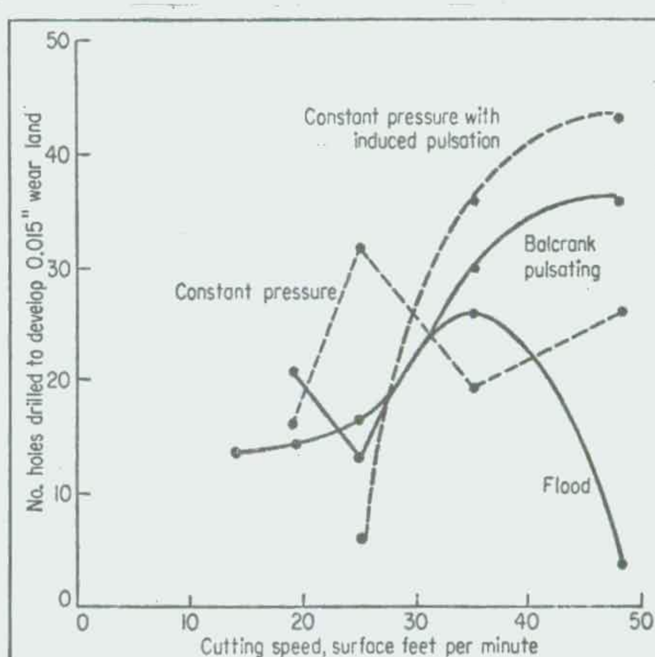


FIG. 2. Effect of pulsating coolant on drill life

1. KULETZ, JOSEPH

2. DRILLING BY EAR

3. AMERICAN MACHINIST, 1966, Vol. 110, No. 14, pp. 63-65

4. Drilling holes as small as 0.020 in. in diameter and up to 3/4" deep is done in a "silent" room so the operators can listen to the drill. An experienced operator can tell by the sound whether a chip is well formed or ragged. This tells the operator how long he can leave the hand fed tool in the workpiece before it has to be withdrawn and cleaned.

1. LINDBERG, H. C.

2. OIL COOLS DRILLS AT 750 PSI

3. AMERICAN MACHINIST/METALWORKING MANUFACTURING, 1966, Vol. 110, No. 9, pp. 101

4. High pressure coolant (750 psi) is introduced through oil holes at each step of a three step carbide tipped oil hole drill to flush out the chips generated in drilling dual filter heads. The hole is drilled to a depth of 6 in. which required the tools to be pulled back a number of times to clear the chips before the introduction of the high pressure gun drilling oil. The drills are cam fed without drill bushings and this has increased production by nearly 325%.

1. ANONYMOUS

2. DUAL CONE ANGLE SPEEDS DRILLING OF HARD STEEL

3. MACHINERY, 1966, Vol. 72, No. 7, pp. 176

4. East German engineers tried three different point configurations in drilling austenitic heat-resistant steel containing chromium, nickel, molybdenum and titanium.

   One point had a 118 degree angle; one had a 170 degree angle with a centering point; and one had a 135 degree angle at the center with a 70 degree angle at the periphery.

   Adjusting conditions so that the drills lasted for a total drilling length of 2000 mm with a feed of 0.31 mm per revolution, the standard drill had a limiting cutting speed of 9 meters per min., the flat point drill 9.8 meters per minute, and the dual cone drill 17.5 meters per minute. With a feed rate of 0.63 mm per revolution the dual cone drill had a limiting cutting speed of 11.5 meters per min.

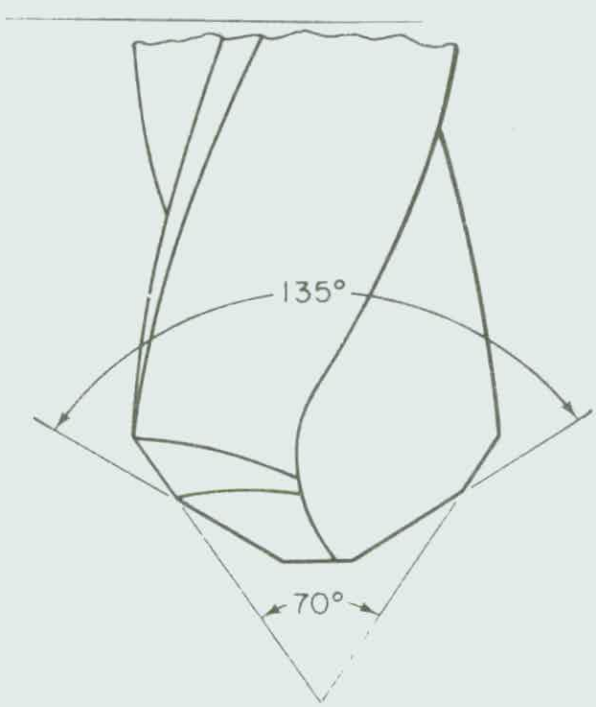


FIG. 1. Dual cone drill point

1. ANONYMOUS

2. REINFORCED DRILLS CAN OUTPERFORM OTHERS

3. MACHINERY, 1966, Vol. 72, No. 8, pp. 212

4. Using a photoelastic stress freezing technique, Soviet engineers have studied the stresses in drills occurring due to torque and thrust.

   Using this technique they have studied drills of conventional profile and "reinforced" drills and have found that the stresses are lower in the reinforced drill.

   When drilling a low chrome steel with 12 mm diameter drills to a depth of 30 mm, the conventional drills broke at a feed of 1.3 mm per revolution while the reinforced drills broke at 1.6 mm per revolution.

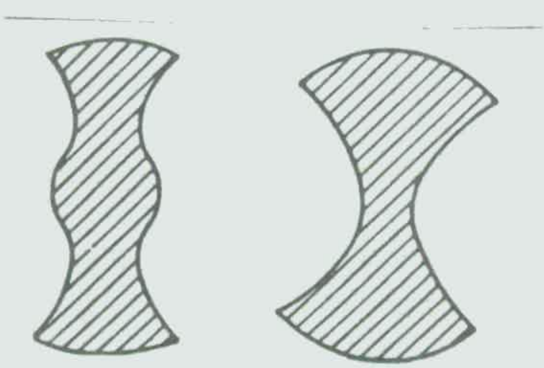


FIG. 1. Reinforced twist drill (left) outperforms standard twist drill (right)

1. ANONYMOUS

2. DRILL LIFE IS INFLUENCED BY THERMOELECTRIC EFFECTS

3. MACHINERY, 1966, Vol. 73, No. 1, pp. 220

4. Soviet engineers have found that drill life is affected by the e.m.f. generated between the tool and workpiece.

   The tool life of carbide drills run at a speed of 30 meters per minute was 8 min. when the workpiece was insulated from the machine and 4 min. when not insulated.

   In some cases the tool life of high speed steel drills could be increased ten-fold when the workpiece was insulated from the machine.

   For carbide drills a current of 10 ma from the workpiece to the tool resulted in a tool life of 11 minutes while a current of 30 ma from the tool to the workpiece caused tool life to fall to 2½ minutes.

1. ANONYMOUS

2. IMPROVED DRILL FOR LIGHTWEIGHT ALLOYS

3. MACHINERY, 1966, Vol. 73, No. 3, pp. 173, 175

4. A new drill in use in Czechoslovakia gives better results than standard high helix drills in drilling aluminum.

   The new drill has a helix angle of 35 degrees. The nominal diameter is D; $R = 0.5D + 0.5$ mm; $J = 0.22D \pm 0.2$ mm; $f = 0.1D \pm 0.1$ mm.

   The flutes and relief surfaces have a high finish.

   With this drill geometry speeds and feeds are higher than with standard drills and the tools lasted 4 to 5 times longer between grinds.

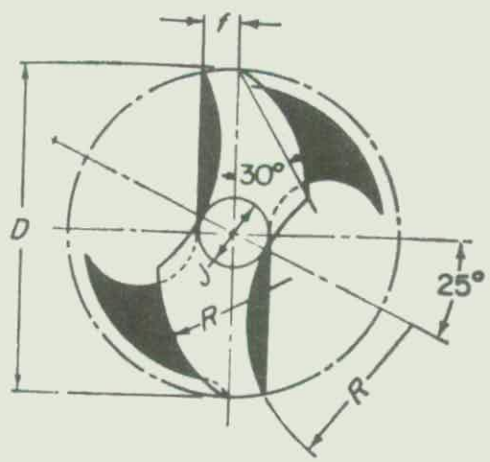


FIG. 1. New drill geometry

1. ANONYMOUS

2. HEAT OF CUTTING CAN FACILITATE MACHINING

3. MACHINERY, 1966, Vol. 74, No. 11, pp. 129

4. A method originated in Czechoslovokia utilizes the heat generated during cutting to facilitate the machining of tough, poorly machinable steels.

   Tests run on Hadfield steel with a 12 percent manganese and 1.3 percent carbon content with drills that were 14 to 26 mm in diameter. The carbide drills had the geometry shown in Fig. 1 and were run at a cutting speed of 50 meters per minute and a feed of 0.1 mm per revolution. The drills produced over 2000 millimeters of hole length between regrinds which is 10 to 20 times greater than standard carbide drills. The temperature immediately ahead of the drill is reported to have reached 700C (1290 F). The hole tolerance is good.

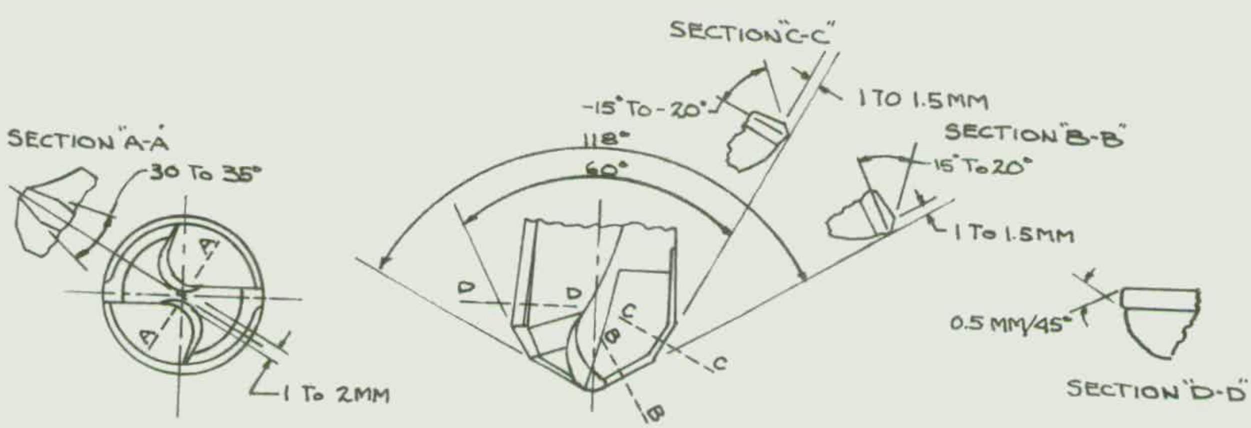


FIG. 1. Carbide drill geometry

1. TICHY, W.

2. THE TIMELY QUEST FOR A PERFECT GENERAL PURPOSE TWIST DRILL

3. PRODUCTION, 1966, pp. 100

4. Tichy lists some of the attributes that a general purpose drill should have. These are:

    1. Stiffness and torsional rigidity. The main factors are flute length, width of lands and web thickness.

    2. Accuracy of drill points. Accurate drill points increase drill life although extremely accurate drill points may result in poorer tool life.

    3. Margins. Narrow margins promote longer drill life

    4. High hardness for high speed tools does not necessarily produce better results.

    5. A black oxide treatment improves tool life.

    6. Drill life is related to changes in helix angle, land width and flute shape and is not influenced by lip clearance and point angle as much.

    7. Web centrality has little effect on drill life or hole accuracy.

1. ANONYMOUS

2. MORE ABOUT DRILL RIGIDITY

3. METAL CUTTINGS BY NATIONAL TWIST DRILL & TOOL CO., 1966, Second Quarter

4. The relative rigidity of a drill section is an indication of the resistance of a unit length of that section of drill to twisting or the torque required to cause a set angle of twist.

   This is found by drawing an inscribed circle on each side of the center web section, Fig. 1.

   The ratio of the inscribed circle diameter d to the drill diameter D is entered on Fig. 2 to determine the relative section rigidity. Fig. 3 is a plot of the ratio of the diameters of the inscribed circle and the drill and relative section compliance which is the inverse of relative section rigidity.

   The torsional compliance of a drill is illustrated in Figure 4. The relative section compliance for each part of the drill is plotted versus drill length from the point. The area under the graph is the compliance of the complete drill.

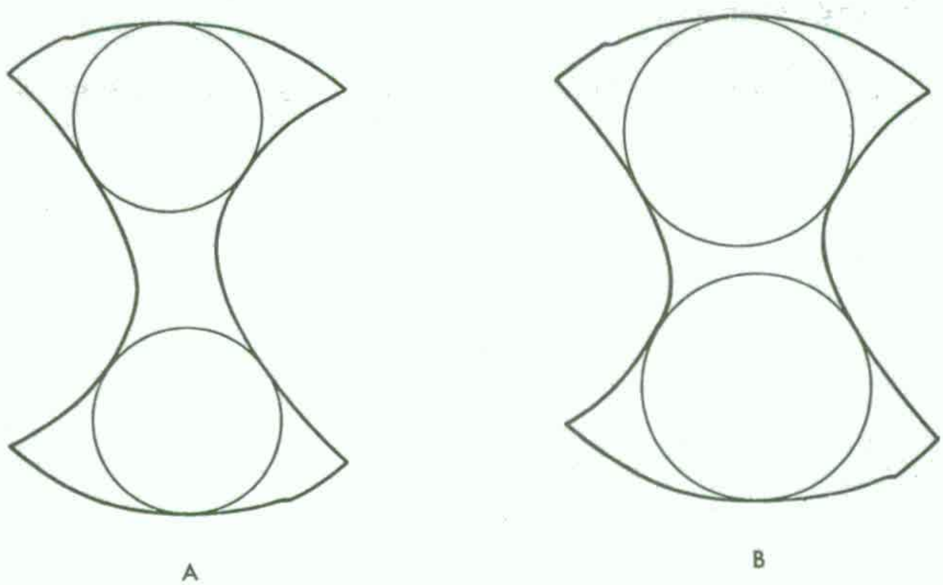
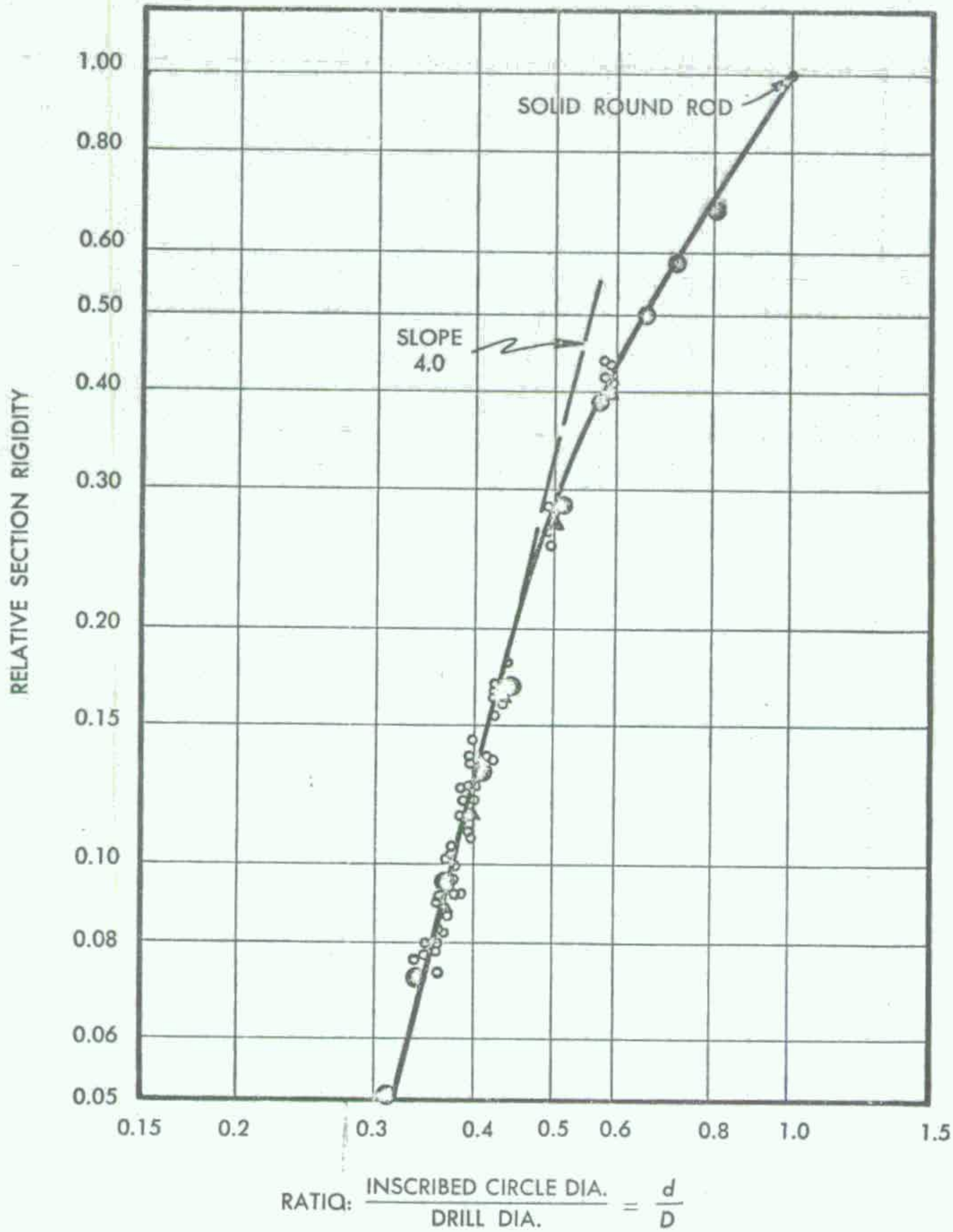


FIG. 1 Transverse cross sections through typical drill flutes showing inscribed circles used for rigidity analysis: A—General Purpose Drill, B—Heavy Duty Drill.



OPEN CIRCLES—ORIGINAL DATA

▲—RECHECK OF ORIGINAL DATA

●—NEW DATA ON ½" DRILLS

FIG. 2. Rigidity vs. ratio of $\frac{d}{D}$

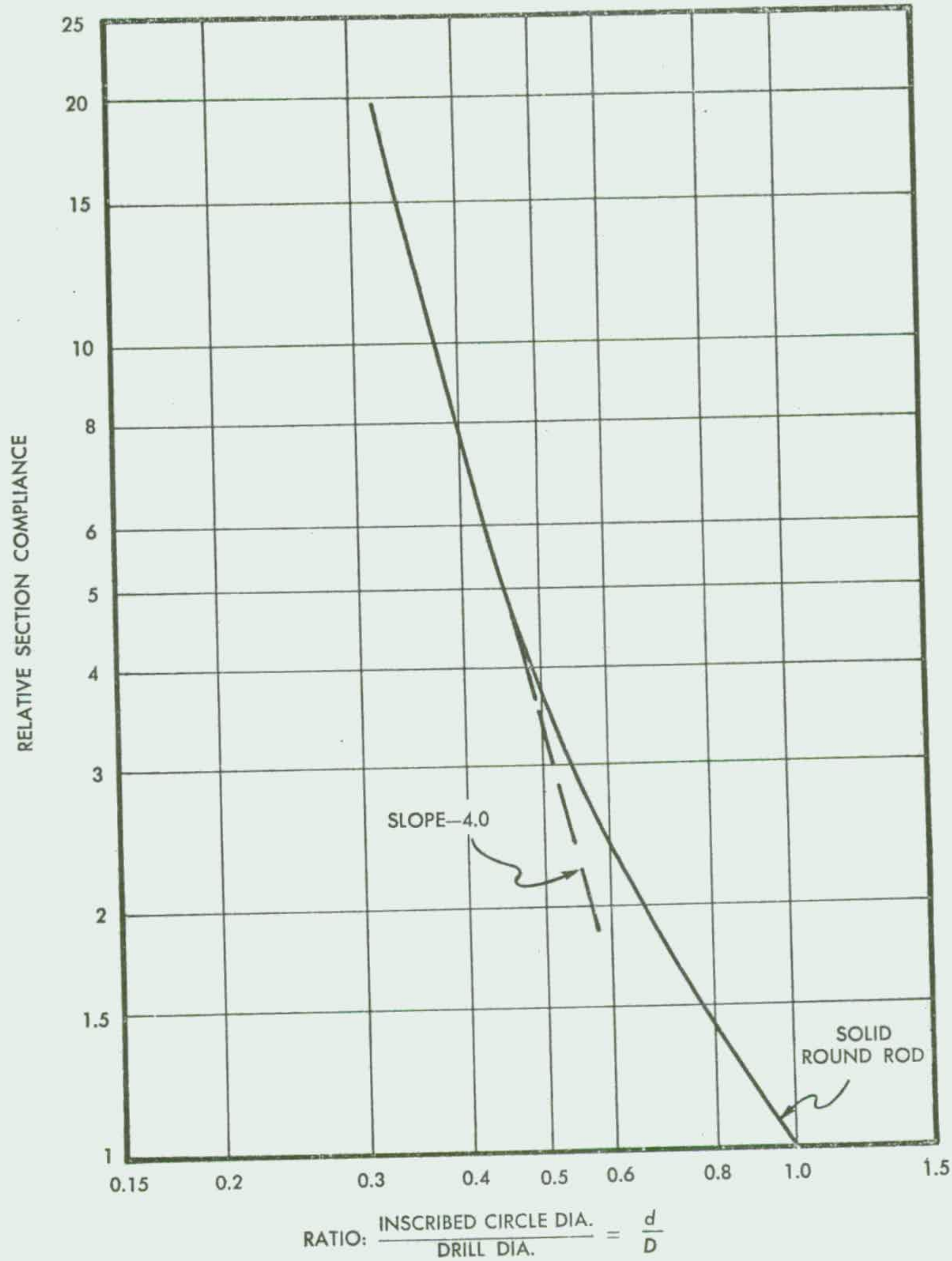


FIG. 3. Section compliance vs. ratio of $\frac{d}{D}$

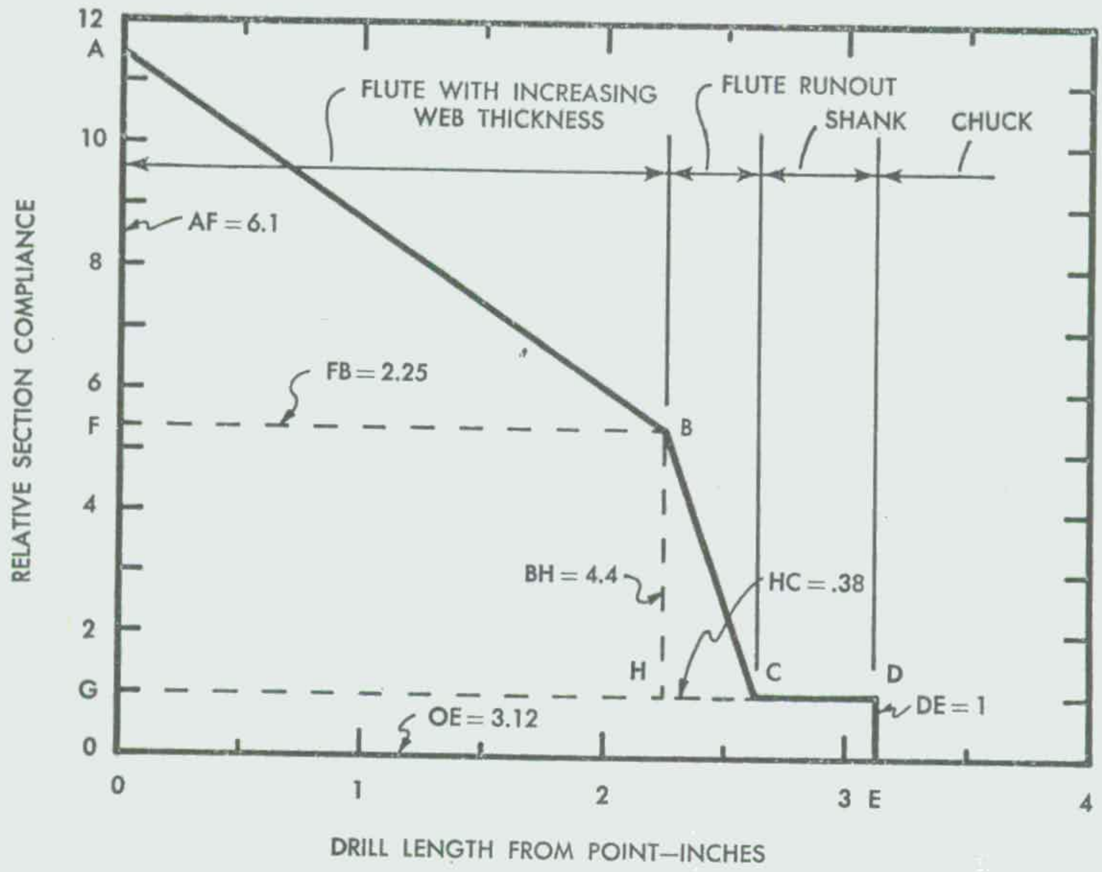


FIG. 4. Section compliance vs. drill length from point

1. SINGPURWALLA, N. D. and KUEBLER, A. A.

2. DRILL LIFE: A MEANINGFUL TEST

3. IRON AGE, 1966, Vol. 198, No. 25, pp. 43

4. Three different criteria were used for determining drill life. The three criteria are:

   1) Change in color of the drill.

   2) Change in sound the drill makes.

   3) Complete destruction of the drill.

      a) Sudden shriek with radial chatter marks in the bottom of the hole.
      b) Red hot drill tip indicating burnout.
      c) An increase in thrust force indicated by rupturing of the drill shank.

   Tests were run in SAE 4340 steel (1/2 to 3/4 in. deep) with 0.0238 in. and 6.8 mm diameter drills. Total drilling time was used as a criterion of drill life.

   An S^2F parameter was found to be meaningful, where S is the cutting speed in feet/min. and F is the feed rate in in./rev. It was found that at one particular value of the parameter, the mean drill life was independent of the way the parameter was formed, Fig. 1.

   For the test conditions used, the following relationship was found:

$$L(S^2F)^C = K$$

   where C and K are constants and L is drill life in minutes. The values of C and K for the three criteria are:

	C	K
Change in color	2.71	475×10^2
Change in sound	3.4	254×10^4
Complete failure	4.92	1315×10^6

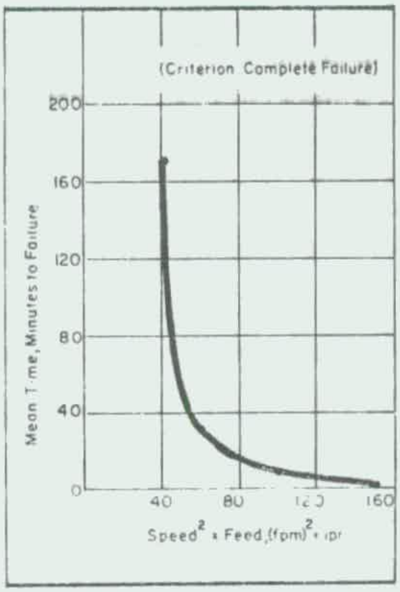


FIG. 1. Measure of drill life

1. ANONYMOUS

2. PULSATING COOLANT IMPROVES DRILLING EFFICIENCY

3. THE TOOL AND MANUFACTURING ENGINEER, April 1966, pp. 52-53

4. To drill holes at a faster rate, produce a better finish on the hole walls and increase the number of holes per tool re-grind is possible with oil-hole drills that deliver a pulsating coolant.

The oil-hole drills establish two one-way flows of coolant. The fluid is delivered to the drill point through the hole and is returned along the flutes. The returning fluid helps to remove the chips. With flood coolant the chips and some of the coolant travel in opposite directions which may starve the point for coolant.

The effect on drill life and penetration rates of speed, feed rate and coolant delivery is shown in Fig. 1 while the effect of coolant delivery on drill life isshown in Fig. 2.

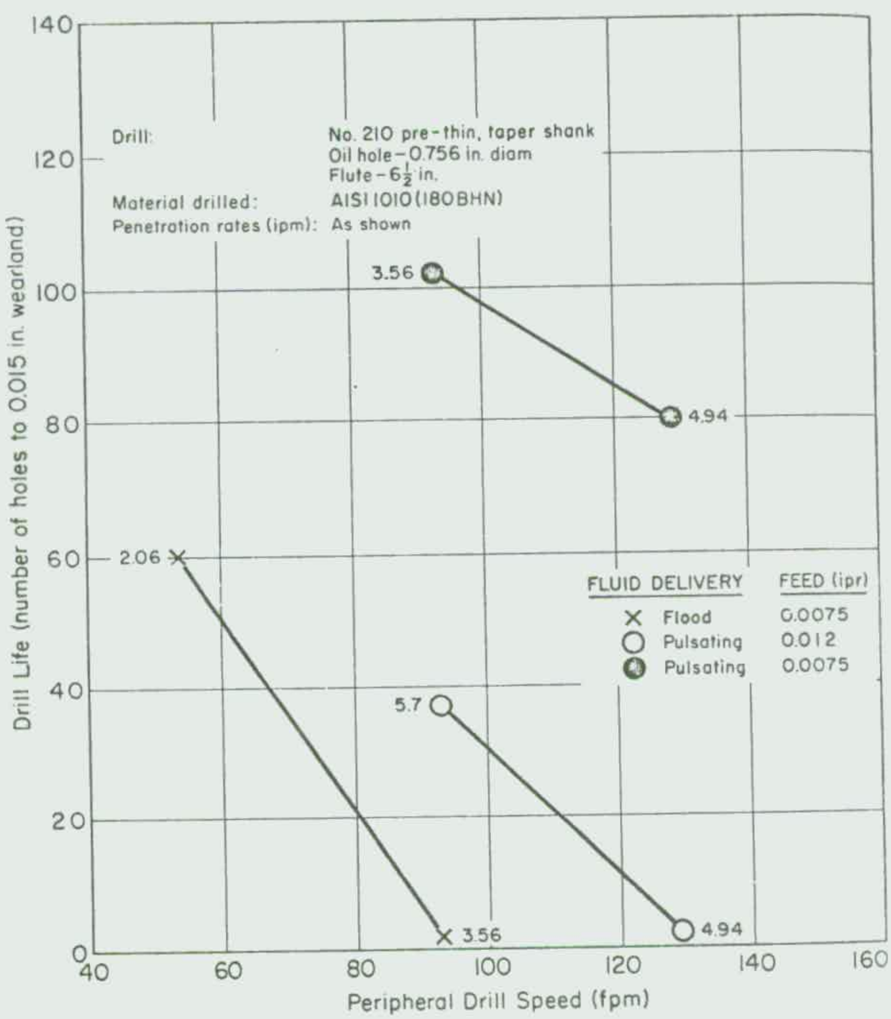


FIG. 1. Effect of some variables on drill life

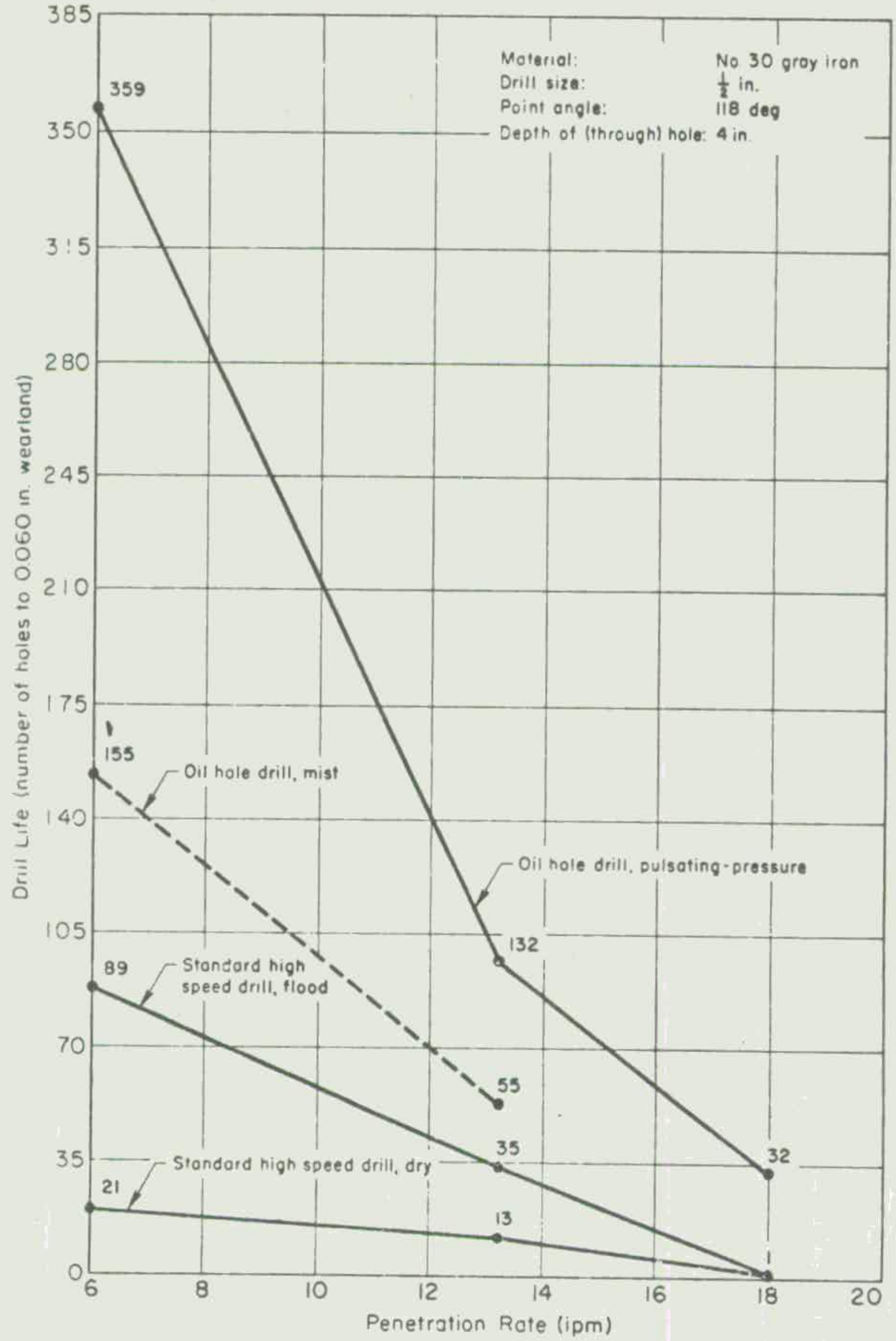


FIG. 2. Effect of coolant delivery on drill life

1. BAKER, ALAN

2. HOW TO TELL WHEN TO SCRAP A USED DRILL

3. CUTTING TOOL ENGINEERING, May, 1966, pp. 7-9

4. A description of two different methods for inspecting drills and determining when they are scrap. Due to the similarity of standard drill lengths, it is difficult for anyone except an expert to determine if a drill of a given length is new or used.

   One method of determining drill life is by measuring the web thickness. This gives an indication as to whether the drill length has been reduced enough to require thinning of the web.

   The method favored by the author involves determining the length of a drill. The drill is inspected with the gage to determine the overall length or the flute length. This is based on the fact that the usable flute length of a drill is usually 10% and 33% of the original flute length.

1. ANONYMOUS

2. MODIFIED DRILL PERMITS ONE-STEP DRILLING

3. CUTTING TOOL ENGINEERING, July/August, 1966, pp. 17

4. In order to eliminate the necessity of drilling holes undersize and then reaming to size the drill point geometry was modified. For 17/32 in. diameter drills a groove was added on the cutting faces of the drill flute, Fig. 1. The groove is 1/32 in. deep with a .030 radius. This groove, in effect, makes a built-in center drill.

Modified drill permits one-step drilling

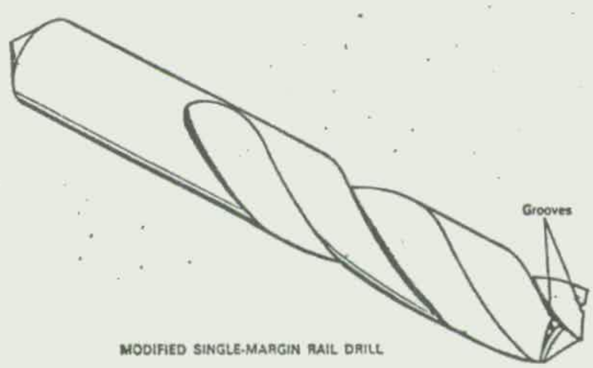


FIG. 1

1. ANONYMOUS

2. DRILL POINT FOR PLASTICS

3. CUTTING TOOL ENGINEERING, July/August, 1966, pp. 17

4. A drill geometry developed for plastics has a point angle of 40 degrees as shown in Fig. 1. With this geometry the drill is claimed to be self-centering, eliminate "bell mouthing", and also eliminate chipping on breakthrough. Due to the freer, cooler cutting action, the drill life is extended.

Fig. 1 Drill Point for Plastics

1. BAKER, A.

2. PRE-SET ROTARY CUTTING TOOLS FOR NUMERICALLY CONTROLLED MACHINES

3. ASTME PAPER NO. MR66-723, 1966, pp. 1-16

4. The advantage of being able to position an N/C machine within 0.005 in. is lost when the drill has a 0.002 in. runout in its holder and the drills cutting edges are 0.005 in. eccentric to the drill.

   To insure the concentricity of the drill, collets are finding increasing use over three jaw chucks.

   Average values for drill lip concentricity are given in Table la for new drills, with recommended values shown in Table lb.

   The flute length of the drill should be kept as short as possible for maximum tool life and hole quality.

   When a roll stamp is used to identify the drill shank as to size and brand, the raised portion of the stamp should be limited. If the stamp has raised the metal 0.003 in. on one side of the shank, the drill will be 0.003 in. off center in the collet and have a runout of 0.006 in. This can also be eliminated by electrochemically etching the identification.

1. SINGPURWALLA, N. D. and KUEBLER, A. A.

2. A QUANTITATIVE EVALUATION OF DRILL LIFE

3. ASME PAPER NO. 66-WA/PROD-11, 1966

4. In defining drill life the authors used three criteria. They are: 1) a change in color of the drill, the end of the drill becomes dark blue for the depth of the hole; 2) a change in sound as detected by an experienced operator; 3) complete failure of the drill indicated by chatter marks at the bottom of the hole, a loud "scream" or a beam out of the drill corners.

   A logarithmic relationship between drill life, measured as total drilling time, and the speed and feed of the drill existed. The general relationship is $L\ (S^2F)^C - K$ where: L = drill life, S = speed of the drill in fpm, F = drill feed in ipr; c and K are constants.

   For the three criteria used the exact relationships are:

   For a change of color: $L(S^2F)^{2.71} = 475 \times 10^2$

   For a change of sound: $L(S^2F)^{3.40} = 254 \times 10^4$

   For complete failure: $L(S^2F)^{4.92} = 1315 \times 10^6$

1. STAENDER, H.

2. BOHRUNGSQUALITAET BEIM BOHREN MIT SPIRALBOHREN (Quality of drilled holes by twist drills)

3. WERKSTATTSTECHNIK, 1966, Vol. 56, No. 11, pp. 546-554

4. The quality of drilled hole can be defined in terms of: a) Diameter, b) Geometry and c) surface finish. Fig. 1 shows the relationship between diameter, geometrical error and measurement.

   Factors affecting the hole quality can be classified as: a) Drill, b) Machine tools and fixtures, c) Drilling condition, d) Use of guide bushing and e) Workpiece.

   The author conducted an extensive investigation of this subject and the results can be given as follows. The variation of diameter obtained for each drill was surprisingly large as shown in Fig. 2. The effect of drilling speed can be seen in Fig. 3 in which increased drilling speed caused the variation of obtained hole diameter to increase.

   In Fig. 4 it is indicated that the effect of wear on the corner of the drill has a negligibly small effect.

   The effect of workmaterial on the hole diameter was presented in Figs. 5, 6, and 7. In these figures it is interesting to note that cast iron (Fig. 7) allowed superior dimensional tolerances to be obtained as compared with the Aluminum Alloy (Fig. 5) and carbon steel (Fig. 6).

   In regard to roundness error, it was observed that the aluminum material had a larger error than steel and cast iron, i.e. drilling light metal tends to produce large roundness error. However, the effect of drilling condition on the roundness error can be disregarded as shown in Fig. 8.

   Surface quality of the drilled inner surface depends upon material and drilling condition. The investigation ascertained that the combination of drilling speed and feed rate affect the surface roughness. Drilling aluminum alloy using a large feed rate and low drilling speed, produced a better surface finish than the opposite case as shown in Fig. 9. It was found that in drilling steel, opposite results from those of drilling the aluminum alloy were obtained.

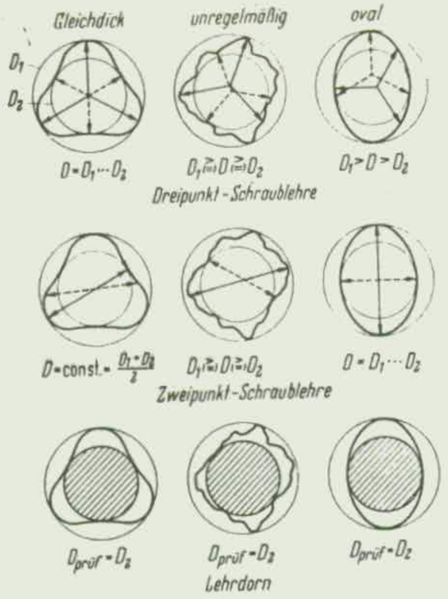


FIG. 1. Relationship between diameter, geometry and their measurements

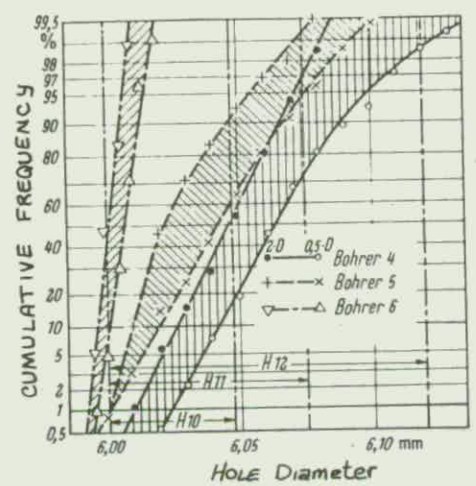


FIG. 2. Variation of diameter by individual drills

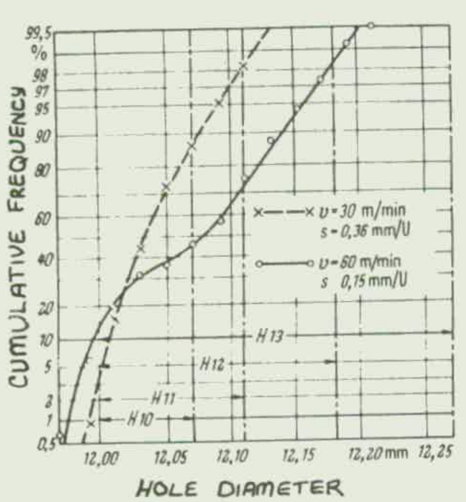


FIG. 3. Effect of drilling speed on diameter variation

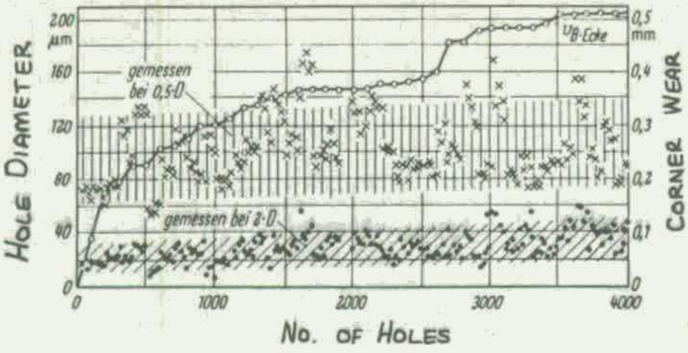


FIG. 4. Effect of drill wear on hole diameter

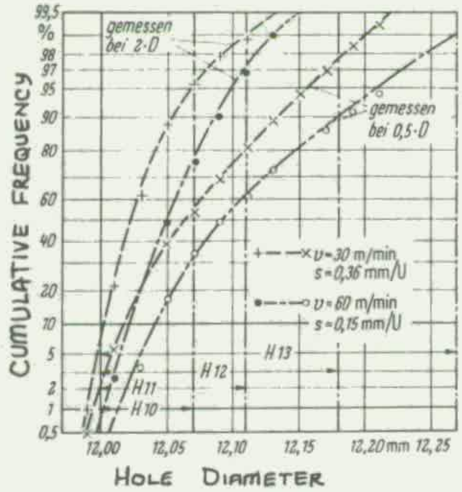


FIG. 5. Hole diameter after drilling Aluminum Alloy

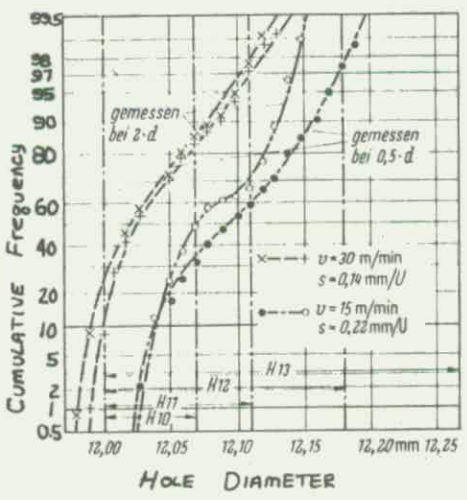


FIG. 6. Hole diameter after drilling carbon steel

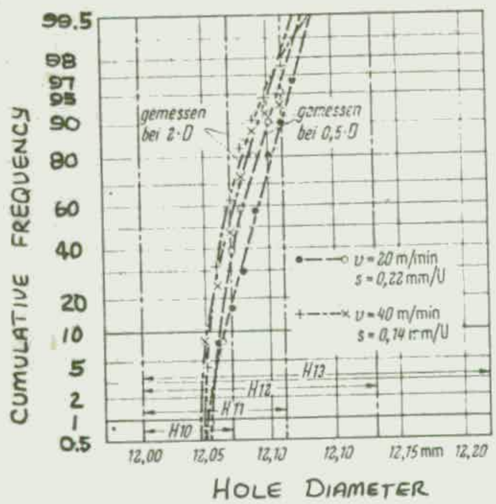


FIG. 7. Hole diameter after drilling cast iron

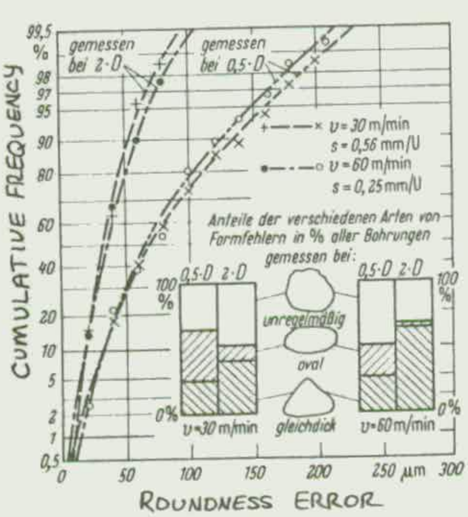


FIG. 8. Roundness error obtained drilling Aluminum Alloy

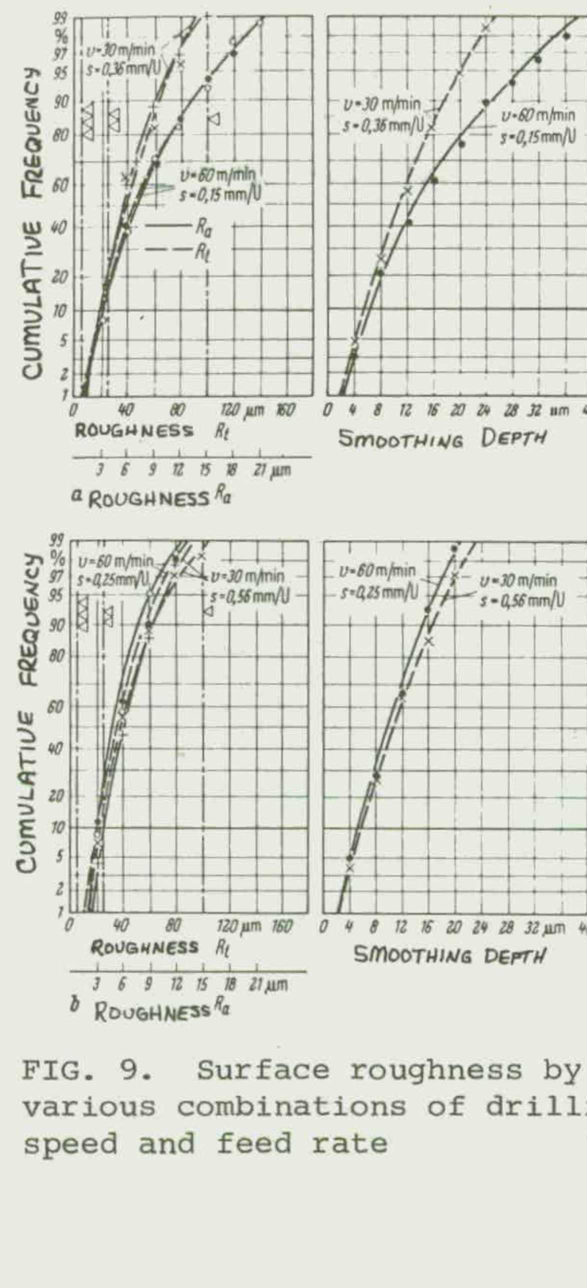


FIG. 9. Surface roughness by various combinations of drilling speed and feed rate

1. ANONYMOUS

2. A NEW ERA FOR DRILLING

3. AMERICAN MACHINIST, 1967, Vol. 111, No. 8, pp. 135-138

4. An improvement in penetration rates, drill life and hole accuracy and finish can be obtained by using oil hole drills with a high pressure coolant system.

   With a flood coolant the coolant must flow into the narrow opening at the heel of the drill to get to the cutting edge. The oil hole drills when used with a high pressure delivery system forces the coolant to the cutting edge for better cooling.

   Improvements in equipment are needed in order to realize maximum benefits and savings.

   Spindles, Fig. 1, should be hollow with a coolant inductor at the top. Spindle noses should have a straight bore for straight shank collet chucks or spade drill shanks with a positive drive and holding arrangement, Fig. 2. Toolholders should be straight shank collet chucks with a combination drill stop and coolant inductor. A toolholder presently in use is shown in Fig. 3 with a proposed tool holder.

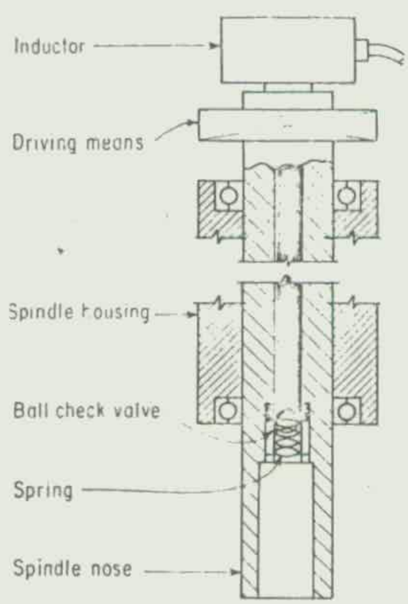


FIG. 1. Improved oil-hole drill spindle

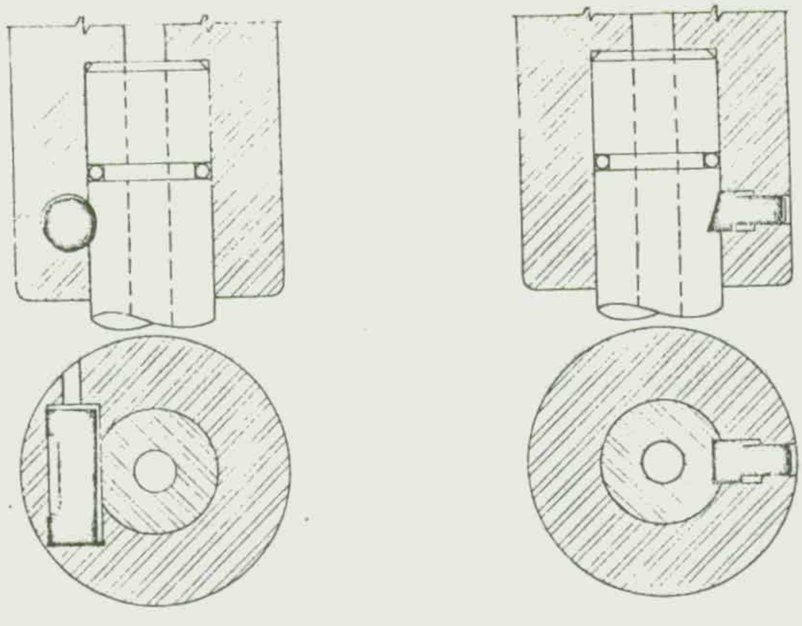


FIG. 2. Spindle noses

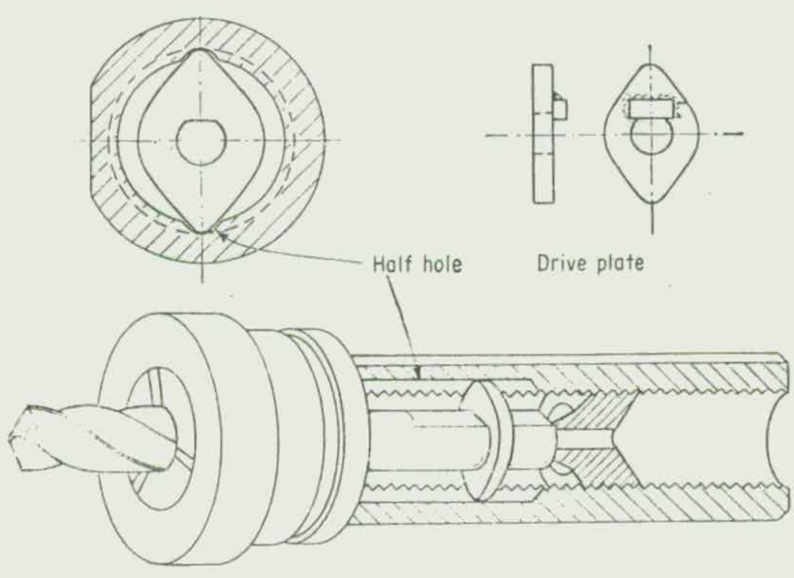


FIG. 3. Proposed toolholder

1. ANONYMOUS

2. SPIRAL vs. CHISEL POINT DRILLS

3. AMERICAN MACHINIST, August 28, 1967, pp. 96-98

4. Drilling tests were conducted on FS 4140 alloy steel, 32 Rockwell C, to compare spiral point and conventional chisel edge drill geometries.

   It was found that the spacing under drill bushings has a marked influence on drill life. With a 1/4 inch spacer chisel point drills had a longer drill life while with a 3/8 inch spacer the spiral point drills showed a marked increase in drill life and outperformed the chisel point drills. The torque and thrust for spiral point drills also showed less fluctuation as the drill bushing spacing was increased indicating a sensitivity to chip packing. A comparison of drill life for through holes is shown in Fig. 1.

   For 3/4 inch drills the spiral point required 32 percent less thrust and 20% less torque than chisel point drills.

   The 3/4 inch diameter spiral point drills produced better hole centering than chisel edge drills although there was no significant difference with 1/4 inch drills. This is shown in Fig. 2.

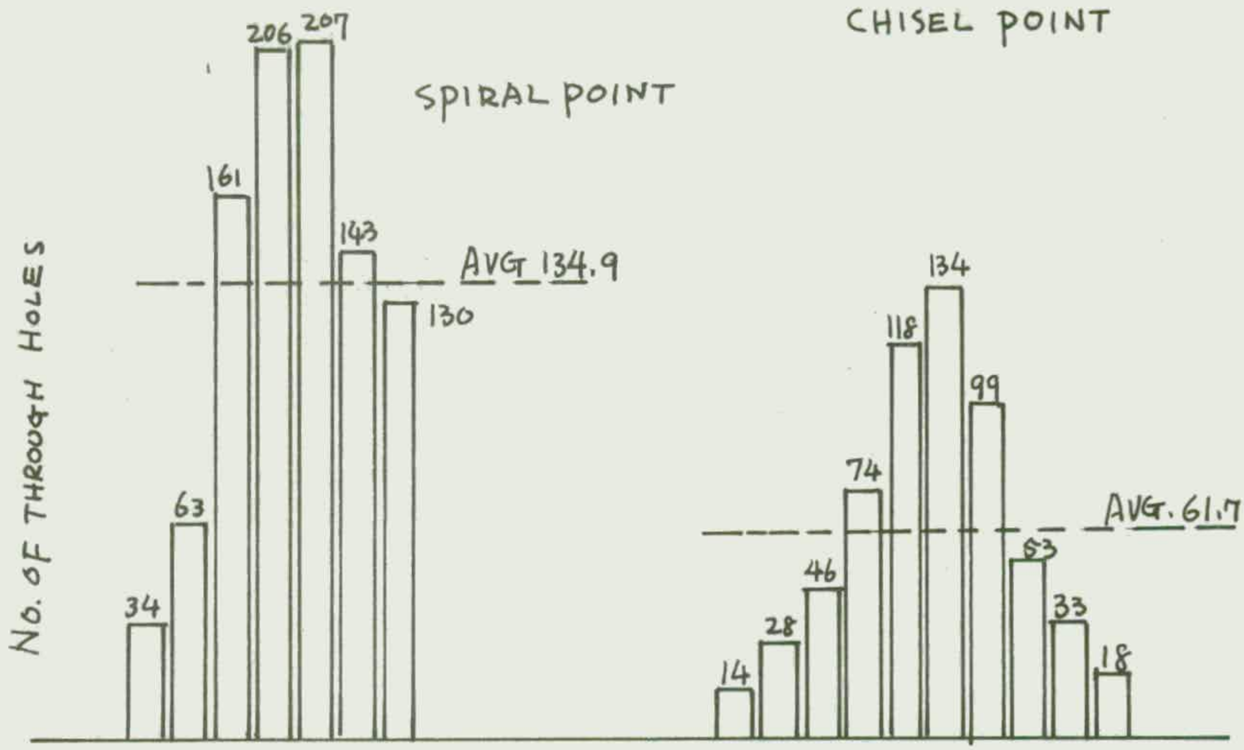


FIG. 1. Comparison of drill life

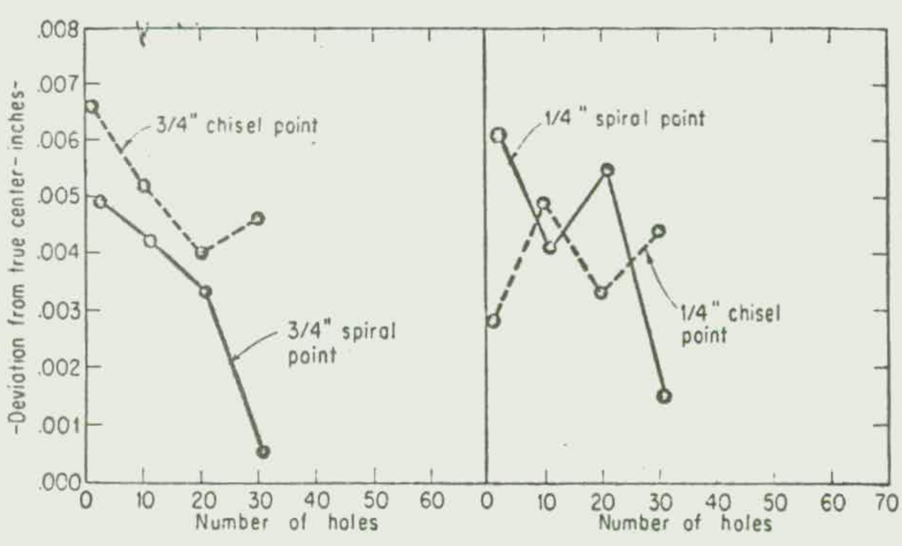


FIG. 2. Hole centering test

1. WESTHOFF, D. R.

2. DRILLING TINY SUPER-DEEP HOLES

3. AMERICAN MACHINIST, Dec. 4, 1967, pp. 147-148

4. The problem of drilling 0.025 in. diameter electrolyte holes up to 5 inches deep in EDM electrodes was solved by a device that allowed the workpiece to be fed into the drill by fingertip pressure, thus allowing for sensitive monitoring of thrust forces.

   Special HSS drills with concentric webs, long shanks and conventional point geometry are used. The drills have a 3/8 inch flute length for drills of 0.010 in. diameter and up to 3/4 in. for 0.020 to 0.050 in. diameter drills.

   With short flute lengths repeated withdrawal of the drill to clear chips (woodpeckering) is necessary. A penetration of 0.050 in. in graphite electrodes for a 0.025 in. diameter drill with 3/4 in. flutes was possible while a penetration of only 0.010 in. was possible in electrodes of aluminum, copper, silver-tungsten and steel. A dial indicator is used so that the penetration in the metal electrodes can be visually determined.

   In order to eliminate the drill from "whipping" and producing an enlarged and misaligned hole, the drill is stubbed to about 3/8 to 1/2 in. when starting a hole. It is extended another 1/2 in. as the depth of the hole warrants.

1. ANONYMOUS

2. QUALITY OF DRILLED HOLES IS STUDIED

3. MACHINERY, 1967, Vol. 73, No. 12, pp. 148, 150

4. The Production Group of the German Engineering Society studied the quality of drilled holes in over 100,000 drilling tests.

   The materials drilled were an alloy called silumin (9.4 percent silicon), Brinell hardness, 96, a normalized 0.45 percent carbon steel and cast iron with a Brinell hardness of 211.

   It was found that the drilled holes did not exceed the upper tolerance but were under the nominal drill diameter when drilling the steel and light alloy. There was a very pronounced taper in the holes drilled in the light alloy, less of a taper in the steel and a negligible taper in the cast iron.

1. BARASH, M.

2. PLASTIC TAPER SHANK IMPROVES DRILL LIFE

3. MACHINERY, 1967, Vol. 74, pp. 142

4. Life of small drills is prolonged by the use of plastic taper shanks, as shown here. The plastic is molded onto the knurled, cylindrical shank end of the drill. A special sleeve is used to connect the drill and the machine spindle. A Soviet plant reports that drill life between grinds is 50 to 200 percent longer when plastic taper shanks are used. Reasons: the plastic acts as a vibration damper and electrical insulator. Similar techniques can be employed with reamers and end mills.

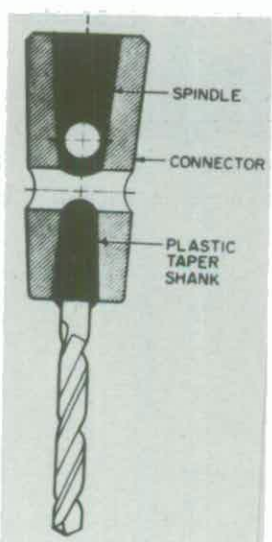


FIG. 1. Plastic taper shank

1. ANONYMOUS

2. TWIST DRILL LIFE IS IMPROVED BY RESEARCH

3. MACHINERY, 1967, Vol. 74, No. 1, pp. 149-150

4. Soviet tool manufacturers and tool builders ran tests on twist drill life to arrive at optimum on geometry for maximum drill life.

   The drills tested were 3 to 28 mm in diameter and the end of drill life was established by the characteristic squeal.

   It was determined that drill life was dependent on core thickness, relief angle and margin size.

   For drills 3 to 10 mm in diameter the maximum life is obtained when:

$$K = (0.27\text{-}0.30)d$$
$$f = (0.4 - 0.5)\sqrt[3]{d}$$
$$\alpha = 12.2 + 28.6/d$$

   K = core thickness, d = drill diameter and α = optimum relief angle.

   Drills with the new geometry were run at speeds 25 percent higher than recommended for standard drills and at double the feed rate. They lasted 1.5 to 2.7 times longer than standard drills.

1. WILSON, G. F. and WEINTRANT, J. J.

2. HOW GOOD ARE SPIRAL POINT DRILLS?

3. MACHINERY, 1967, Vol. 74, No. 1, pp. 82-83

4. The tests for comparing the spiral point and chisel edge drills were conducted in FS 4140 steel, oil quenched and tempered to 32 Rockwell C. The high speed steel drills, T-15 and M-2, were accurately ground.

When drilling with 1/4 in. drills, with drill bushings, the recommended spacing between the workpiece and bushing is 1/4 in. Using this spacing the chisel point drills averaged 61.25 holes per drill while the spiral point drills averaged 16 holes. When the spacing was increased to 3/8 in. the life of the spiral point drill increased to 224 holes. This indicates that the spiral point can outperform chisel edge drills where chip packing isn't a problem.

When drilling without drill bushings the spiral point drills produce holes with less angularity, Fig. 1, less deviation from the true center, Fig. 2, and less hole oversize, Fig. 3, than chisel edge drills for both 3/4 and 1/4 in. diameter.

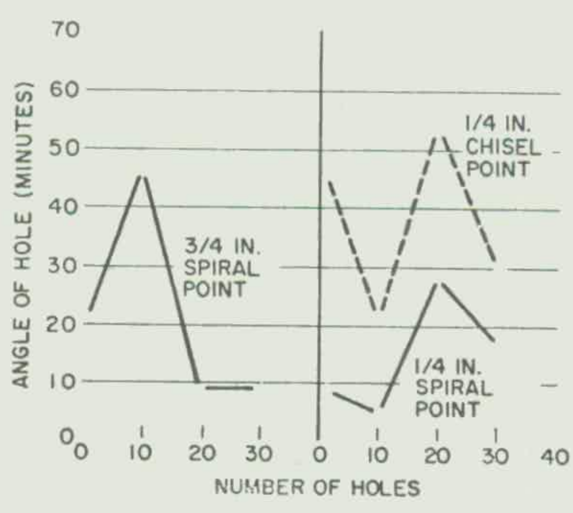


FIG. 1. Hole angularity

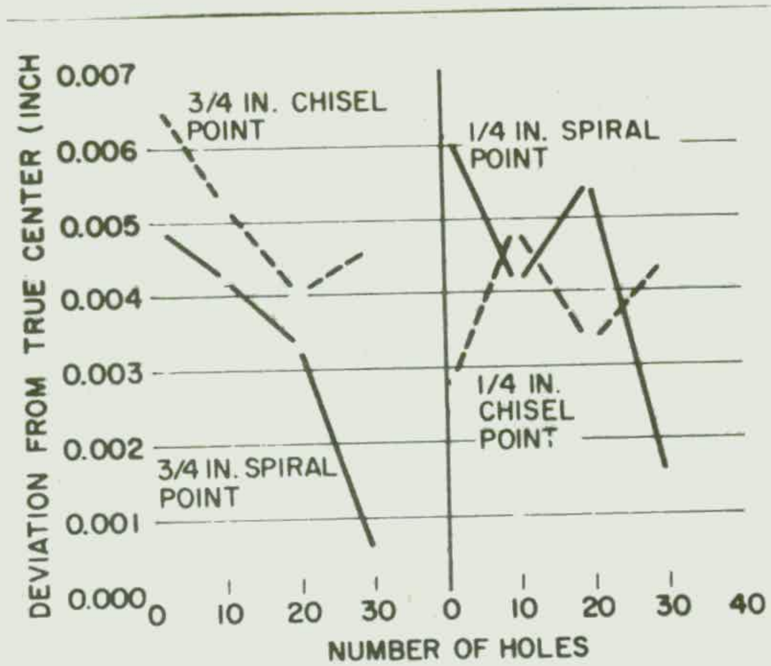


FIG. 2. Deviation from center

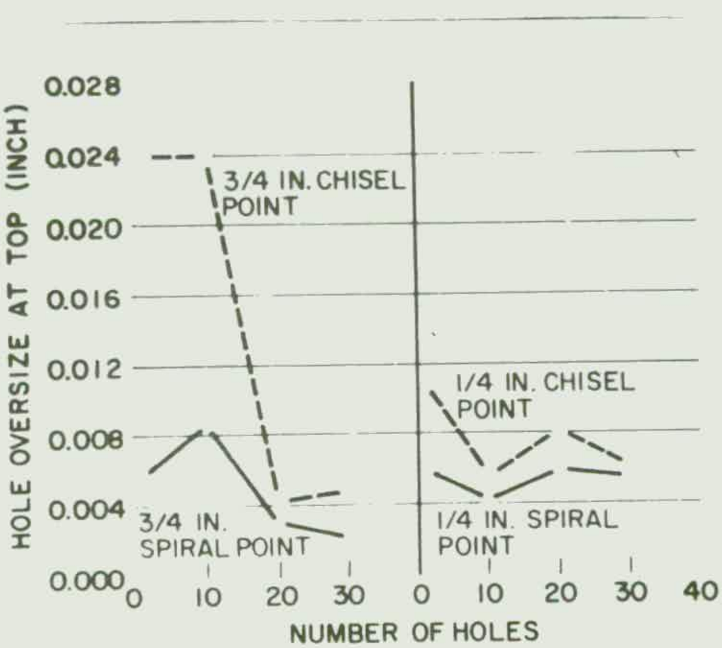


FIG. 3. Hole oversize

1. ANONYMOUS

2. RESEARCH IN PRODUCTION TECHNOLOGY ABROAD

3. MACHINERY, 1967, Vol. 75, No. 5, pp. 109

4. Soviet engineers have developed a thermomechanical process for increasing the strength of small tools.

   Drills of Type T-1 high speed steel are heated to 1260C, quenched to 450C and then twisted through a 2 degree angle 500 times at a frequency of 25 times per second. These drills have a hardness of Rockwell C61-62, which is higher than conventionally treated drills.

   Tool life is reported to be increased 30 percent by this new process.

   For deep hole drilling in medium carbon steel, Soviet researchers claim that the high helix drill shown in Fig. 1 gives six to eight times longer tool life. The drill is made from type T-1 tool steel. In tests that were conducted in drilling holes that had a depth to drill diameter ratio of 15 to 1, tool life was 200 minutes at a speed of 25 mm per min. and a feed rate of 0.10 mm per revolution.

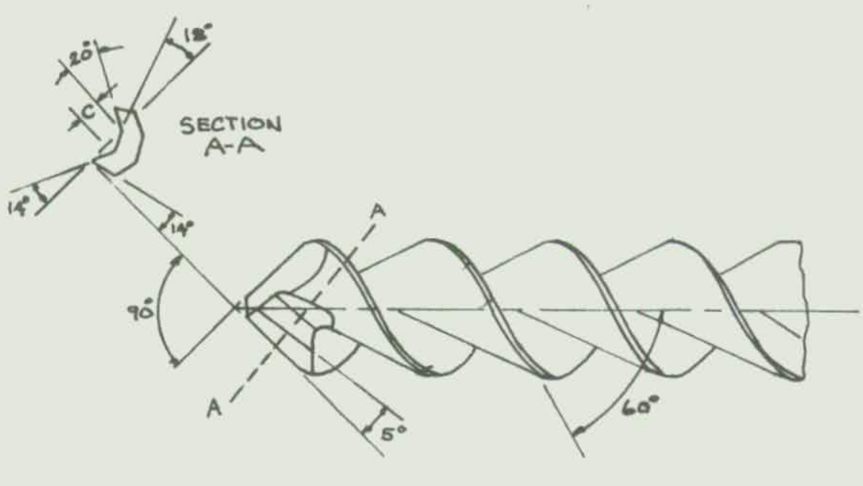


FIG. 1. High helix drill

1. STANISLAO, J. AND JAMES, JR., C. F.

2. A DESIGN OF A TEST SYSTEM TO AID IN CUTTING TOOL SELECTION

3. ASTME TECHNICAL PAPER NO. MR67-191, 1967, pp. 1-18

4. A test is described to assist in determining which of several tools will give the best tool life. Drills of varying point angle from several drill manufacturers were tested with the basis of comparison being temperature rise.

   In order to determine the temperature rise a specimen was placed in a calorimeter filled with water. The temperature of the water before and after drilling, the drilling being done in the water, was recorded and the temperature rise determined.

   Statistical tests were then applied to determine the optimum combination of point angle and drill manufacturer.

1. BROCKMAN, R. W., BURANT, R. O., KENNEDY, R. G., MARROTTE, N. W. and SIKORA, R. E.

2. DRILL DESIGN AND APPLICATION REQUIREMENTS FOR OPTIMUM COOLANT-FEEDING TWIST DRILL USAGE

3. ASTME TECHNICAL PAPER NO. MR67-104, 1967, pp. 15

4. A comparison of oil-hole and regular drills, Fig. 1, was conducted. The coolant was a heavy duty soluble oil (1:20).

   A comparison of the drill life of oil-hole and solid drills in SAE 1018 at various penetration rates is shown in Fig. 2, with the cutting speeds and feed rates shown in Fig. 3.

   As is indicated in Fig. 4, increased penetration rates are also possible with oil hole drills when drilling T-1 structural steel.

   A Meehanite cast iron (BHN 180-197) was also drilled. The effect of penetration rate on drill life is given in Fig. 5. The left half of Fig. 5 is for a constant cutting speed (480 RPM) and a varying feed rate and the right half has a constant feed rate (.024 ipr) and a varying speed.

   By increasing the coolant pressure and flow rate the drill life was increased (Fig. 6). When the feed rate is increased with oil-hole drills, the thrust force did not increase as rapidly as for the conventional drills (Fig. 7).

   As a drill dulls and the torque and thrust increase, the feed and the speed of a drill slow down. By dividing the theoretical penetration rate by the actual rate a penetration efficiency was determined. This efficiency was then used to compare the type of coolant application (single or double nozzle, continuous and continuous plus pulse flow) for solid drills operating horizontally (Fig. 8). Fig. 9 shows the same relationship for oil hole drills with continuous and pulse flow for the coolant.

   With low pressures (25 psi) the low helix oil hole drill produced the best hole with respect to hole oversize while at pressures over 25 psi, the high helix drill performed best (Fig. 10).

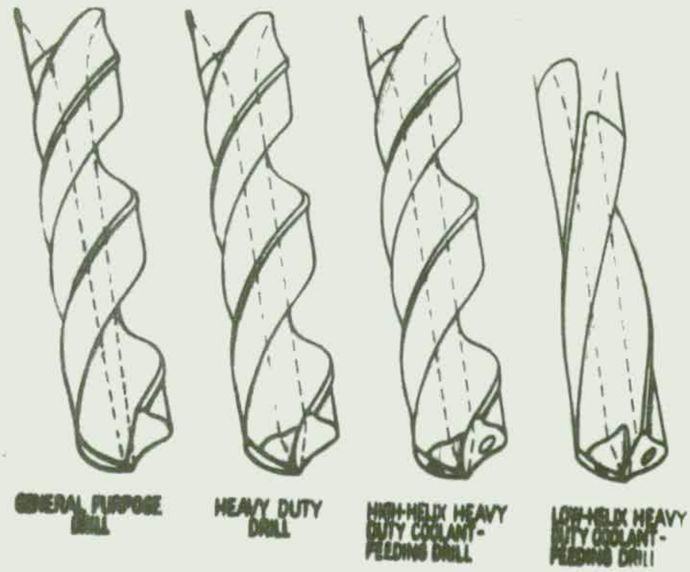


FIG. 1. Web and point details of test drills

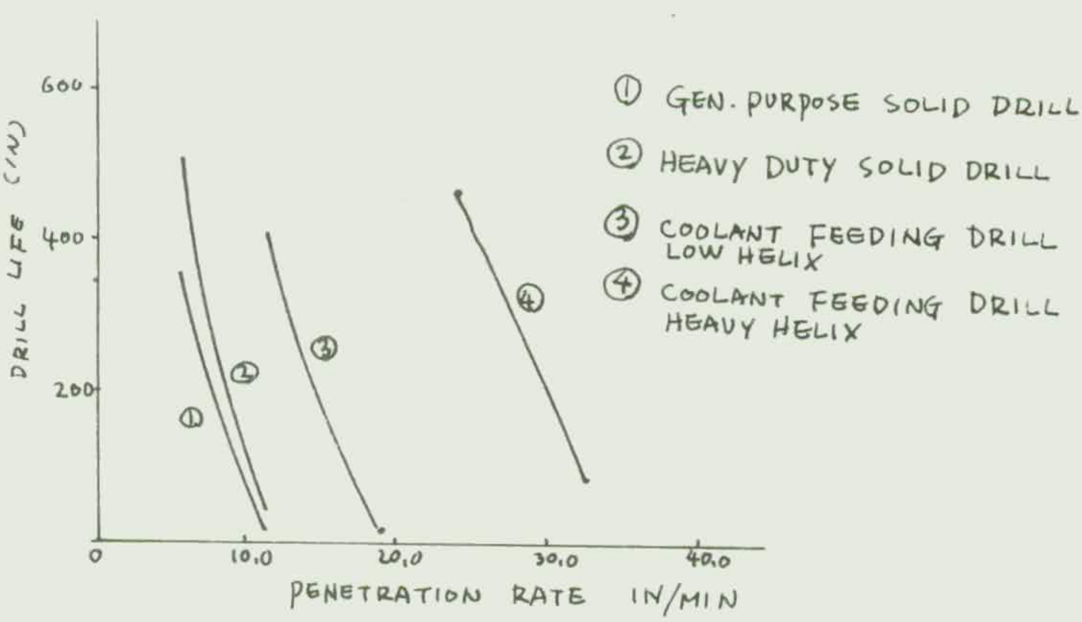


FIG. 2. Drill life vs. penetration rate in SAE 1018

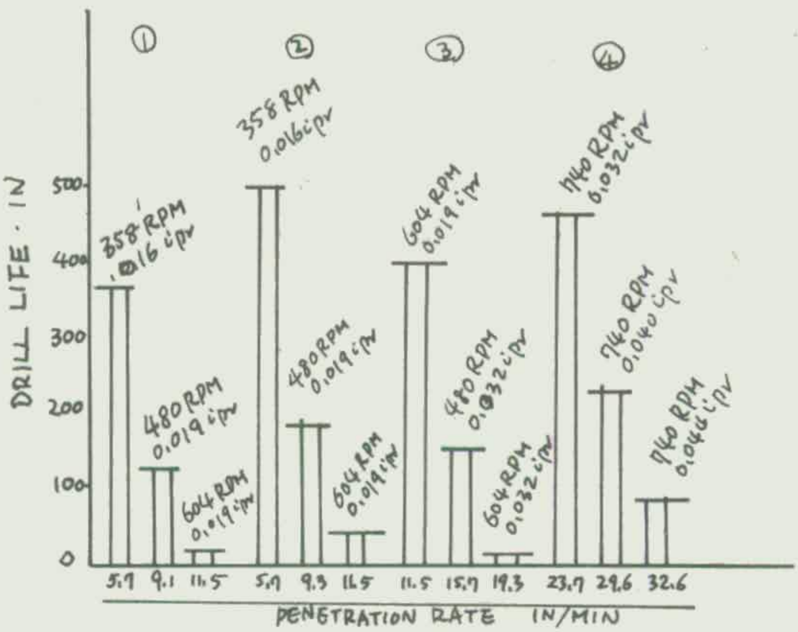


FIG. 3. Speed, feed and types of coolant application used in drilling SAE 1018 with solid and coolant-feeding drills

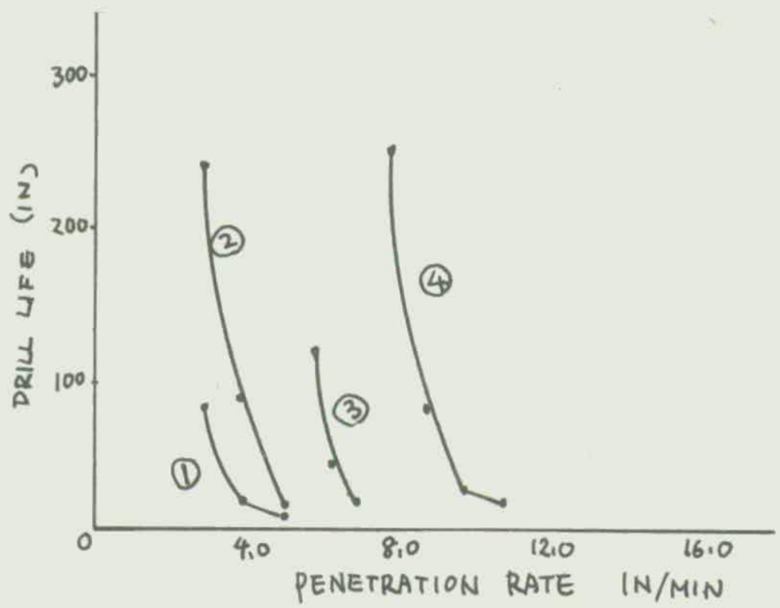


FIG. 4. Drill life vs. penetration rate in T-1 structural steel for solid and coolant-feeding drills

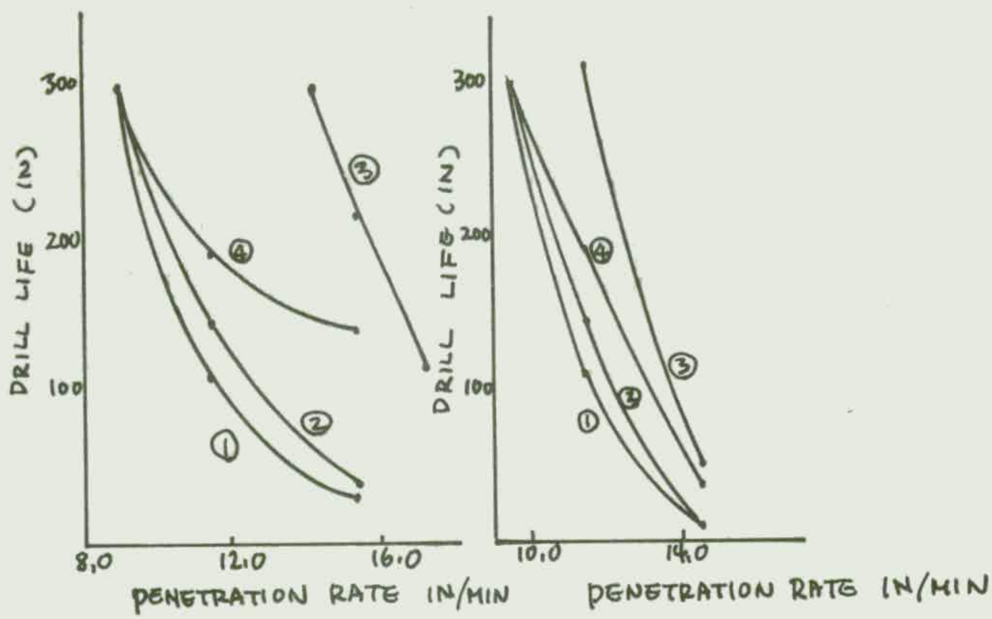


FIG. 5. Drill life vs. penetration rate in Meehanite cast iron

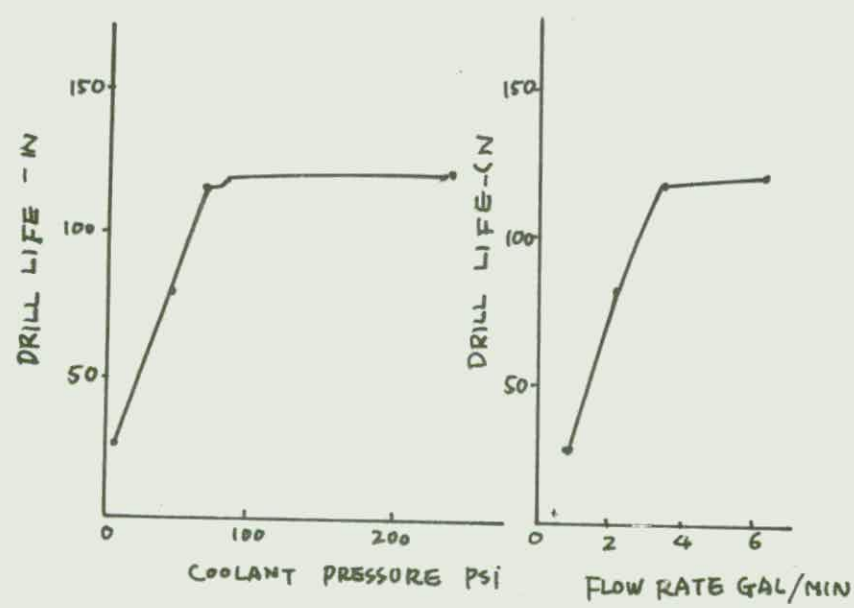


FIG. 6. Drill life vs. coolant pressure and coolant flow rate in T-1 construction steel with coolant-feeding drills

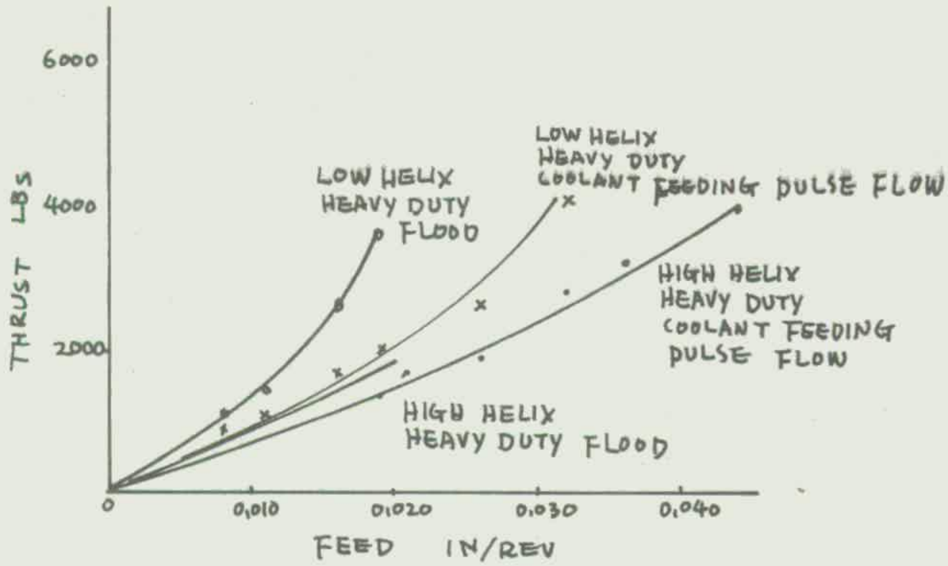


FIG. 7. Thrust forces developed in vertical drilling of SAE 1018 with solid and coolant-feeding drills

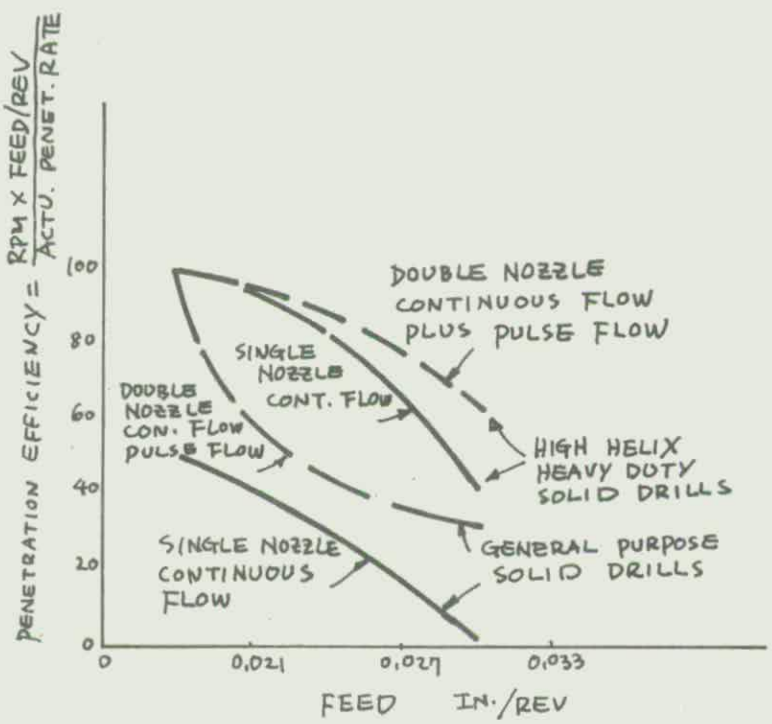


FIG. 8. Horizontal drilling with solid drills at increasing feed rates. Flood coolant application with one and two nozzles

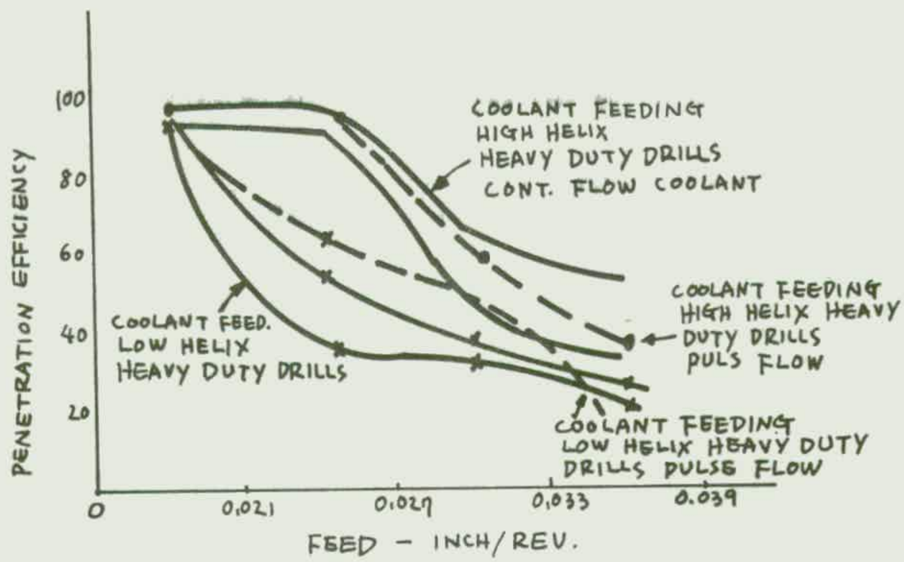


FIG. 9. Horizontal drilling with coolant-feeding drills at increasing feed rates. Continuous flow and pulsing coolant applications

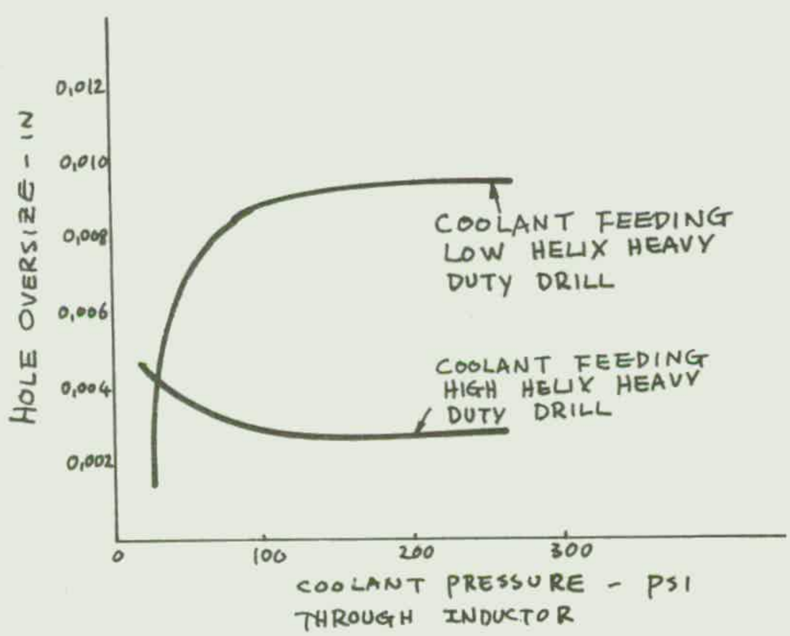


FIG. 10. Horizontal drilling with low helix and high helix coolant-feeding drills using increasing coolant pressures

1. ZLATIN, N.

2. APPLICATION OF CUTTING FLUIDS IN DRILLING

3. ASTME TECHNICAL PAPER, No. MR67-105, 1967, pp. 6

4. A comparison is made between applying a cutting fluid with oil hole drills and flooding the tool.

   The two materials that were used were 17-4 PH stainless steel, solution treated to a 352 BHN and a titanium alloy (6 Al-4V) solution treated and aged to 375 BHN.

   A comparison of a water base and an oil base cutting fluid is shown in Fig. 1. At the lower cutting speeds the two fluids applied by flooding the tool were almost equally effective. At speeds above 55 fpm the water base fluid was superior due to its ability to absorb the increase in heat generated at the higher speed.

   Standard drills without oil holes with a 29 degree helix angle and screw machine length drills with oil holes (15 degree helix) were compared using flood cooling. The standard drill produced 250 holes at a cutting speed of 67 fpm while screw machine drills speed had to be reduced to 51 fpm to produce the same number of holes (Fig. 2). When the screw machine drill was used as an oil hole drill the cutting speed was increased to 85 fpm for a drill life of 250 holes. Similar results were obtained with a water base fluid when drilling ½ in. deep (Fig. 3) and 1.0 in. deep (Fig. 4).

   To eliminate the tendency of the titanium to smear on the drill margin, it is necessary to get an active cutting fluid to where the cutting takes place. When applying the cutting fluid by flooding an increase in cutting speed from 34 to 43 fpm reduced drill life from 250 holes to less than 25 holes for both the screw machine drill and the standard drill. By using the screw machine drill as an oil hole drill a tool life of 250 holes was obtained at a cutting speed of 85 fpm (Fig. 5).

   The conventional drill using flood cooling was compared to the oil-hole drill using flood and oil-hole cooling. In both cases (Fig. 6) the oil hole drill outperformed the conventional drill.

   When drilling the titanium with oil hole drills a chlorinated oil provided the best tool life (Fig. 7).

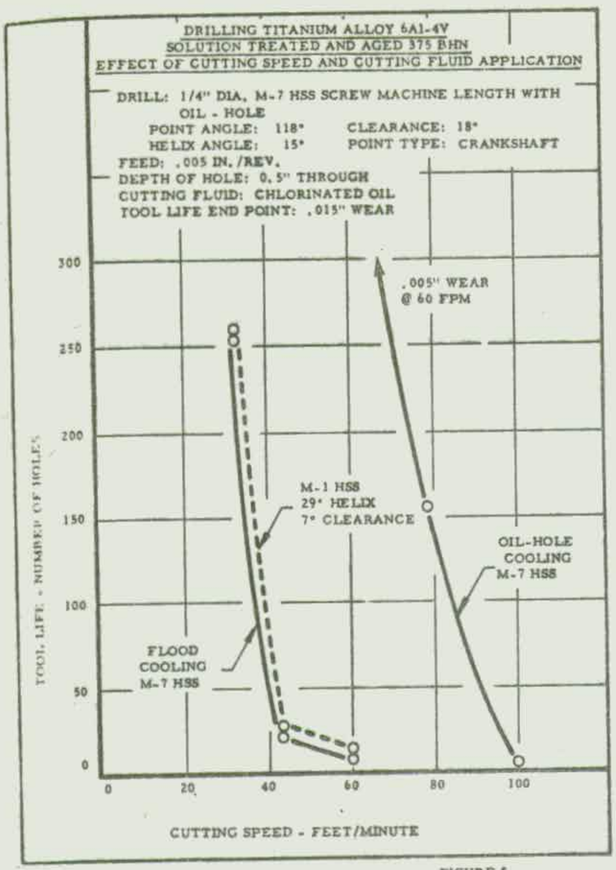


FIGURE 5

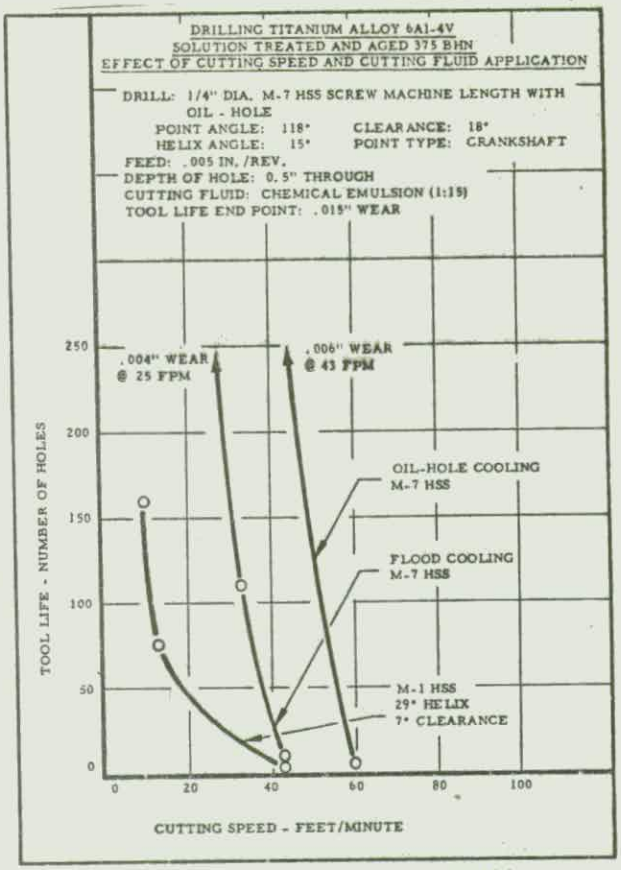


FIGURE 6

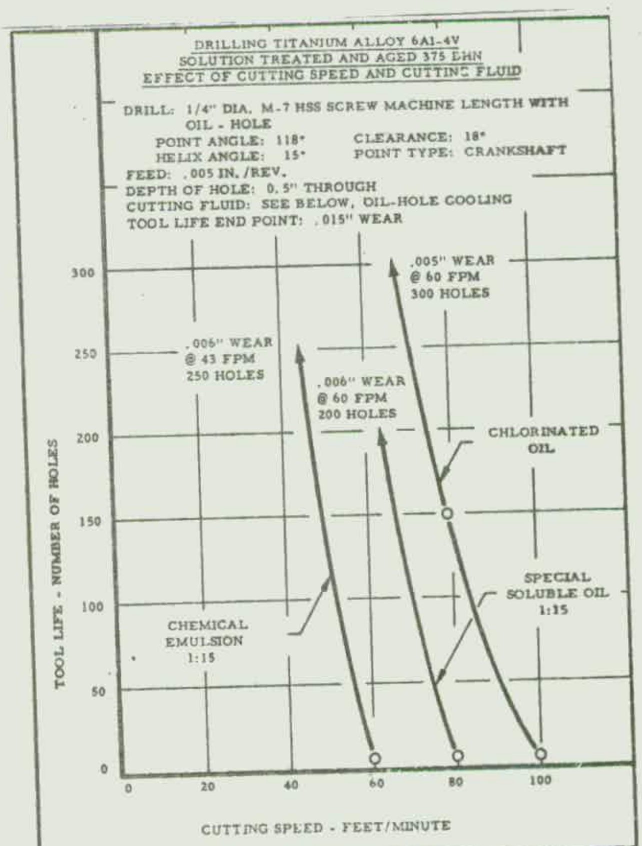


FIGURE 7

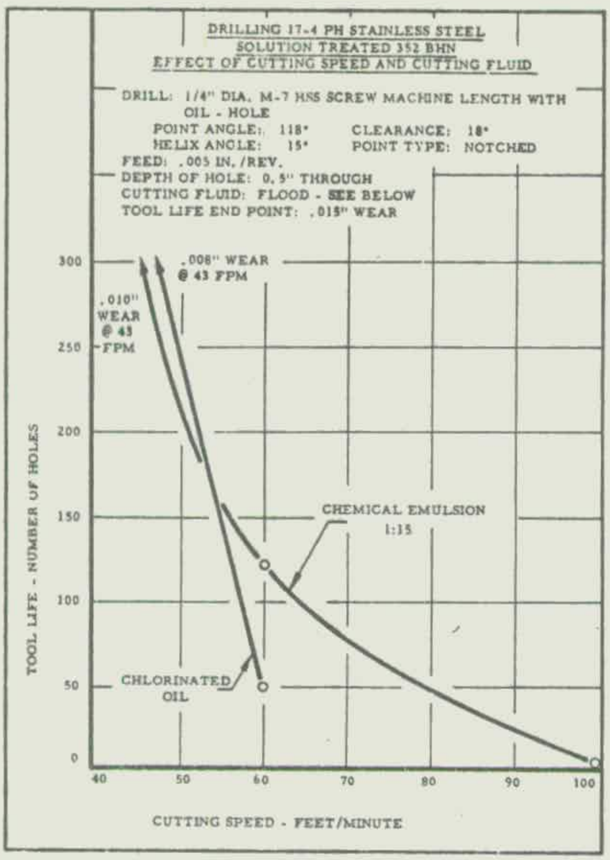


FIGURE 1

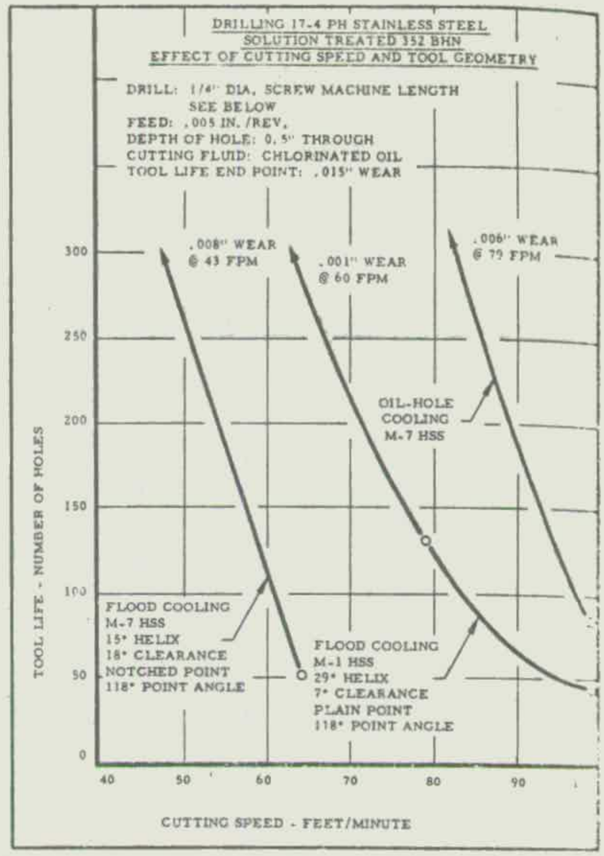


FIGURE 2

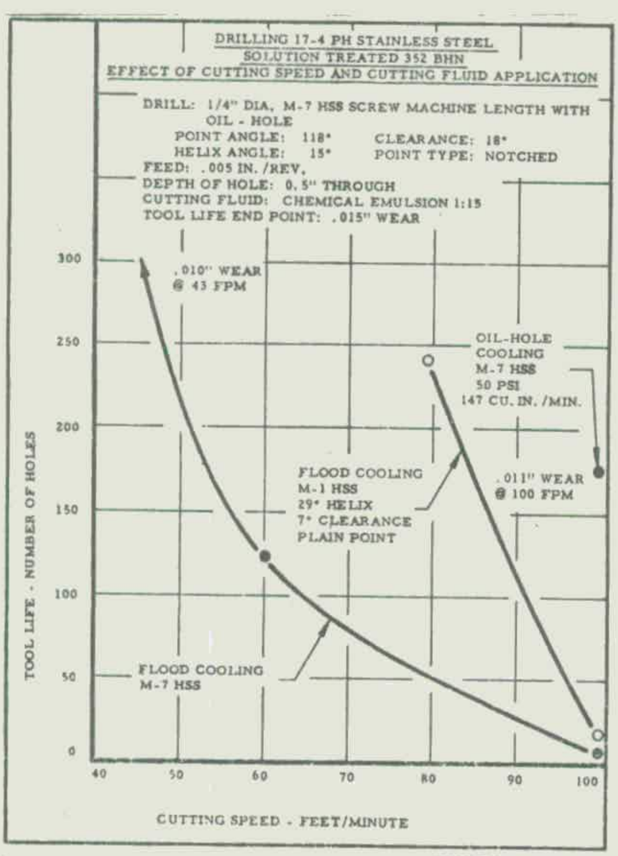


FIGURE 3

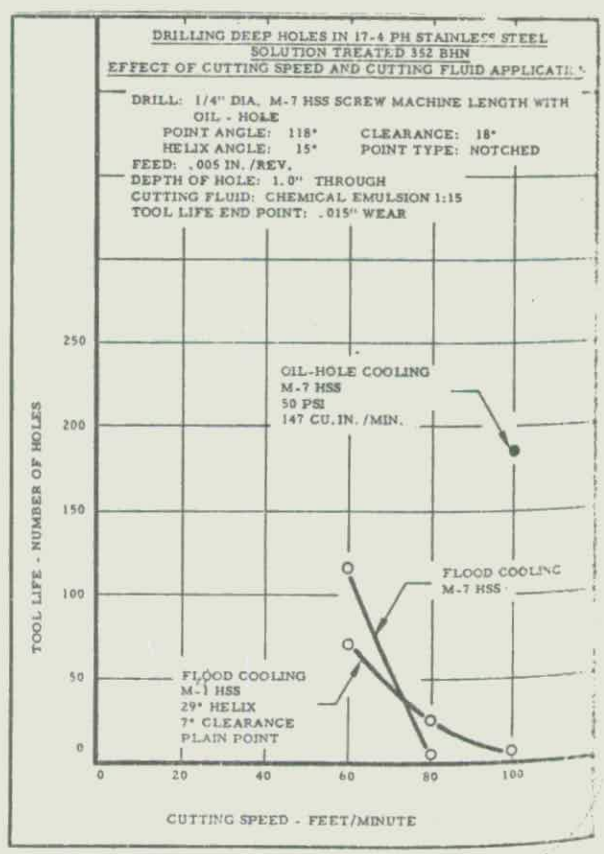


FIGURE 4

1. ANONYMOUS

2. BREAKING TORQUE OF TWIST DRILLS

3. METAL CUTTINGS BY NATIONAL TWIST DRILL & TOOL CO., Fourth Quarter, 1969

4. Tests were conducted in which the torque required to break drills was determined. It was found that the breaking torque varied with the 2.8 power of the drill diameter. This means that by increasing the drill diameter by 50% the torque required to break the drill increases by about 3 times.

   Drill design had little effect on the breaking torque although heavy duty drills required about 25% higher breaking torque than other type drills (Fig. 1).

   The safety factor or the ratio of breaking torque to operating torque increases with increasing drill diameter (Fig. 2).

   It was observed that thrust force and hard case surface treatments had little effect on breaking torque.

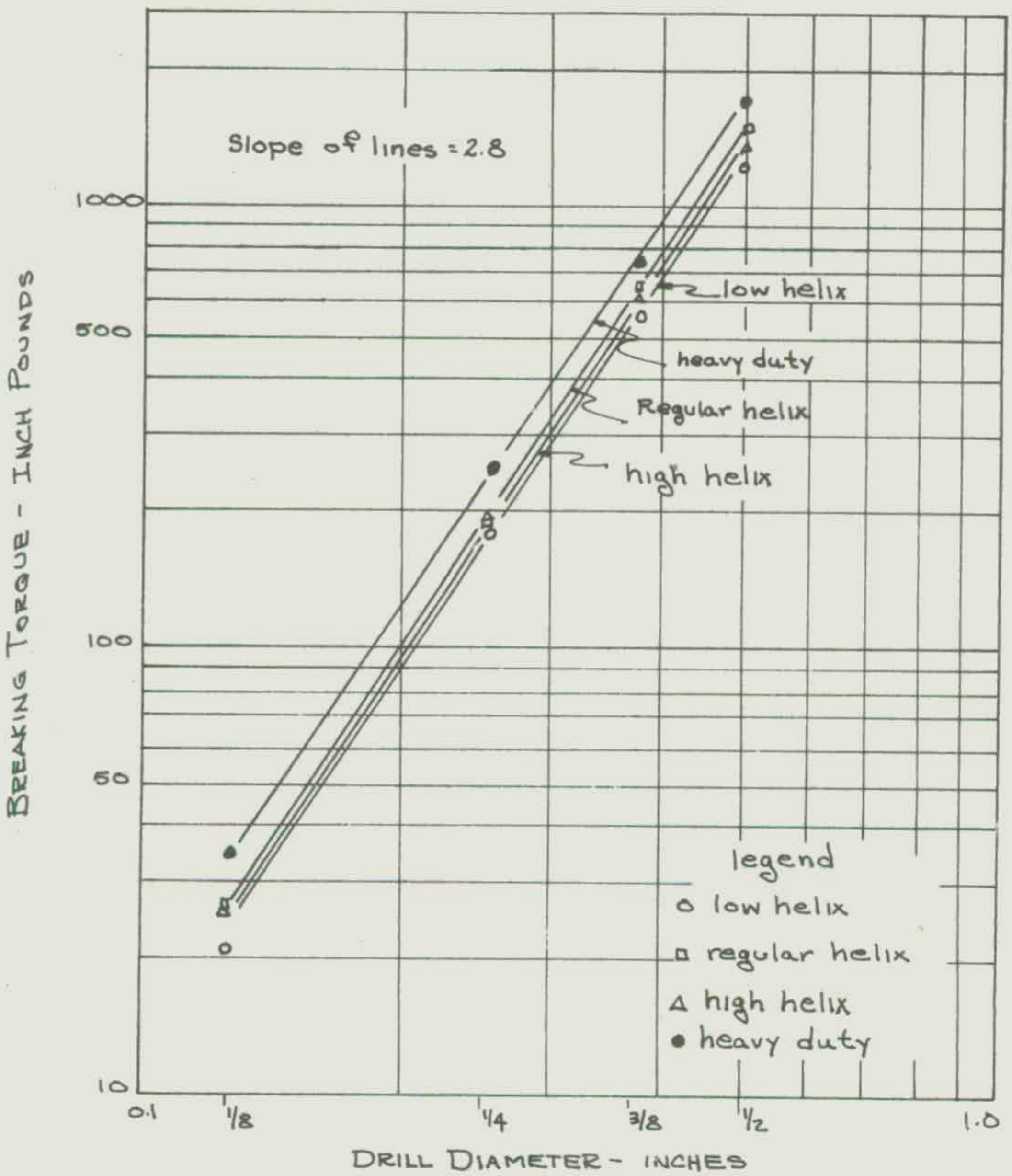


FIG. 1. Influence of drill diameter on breaking torque

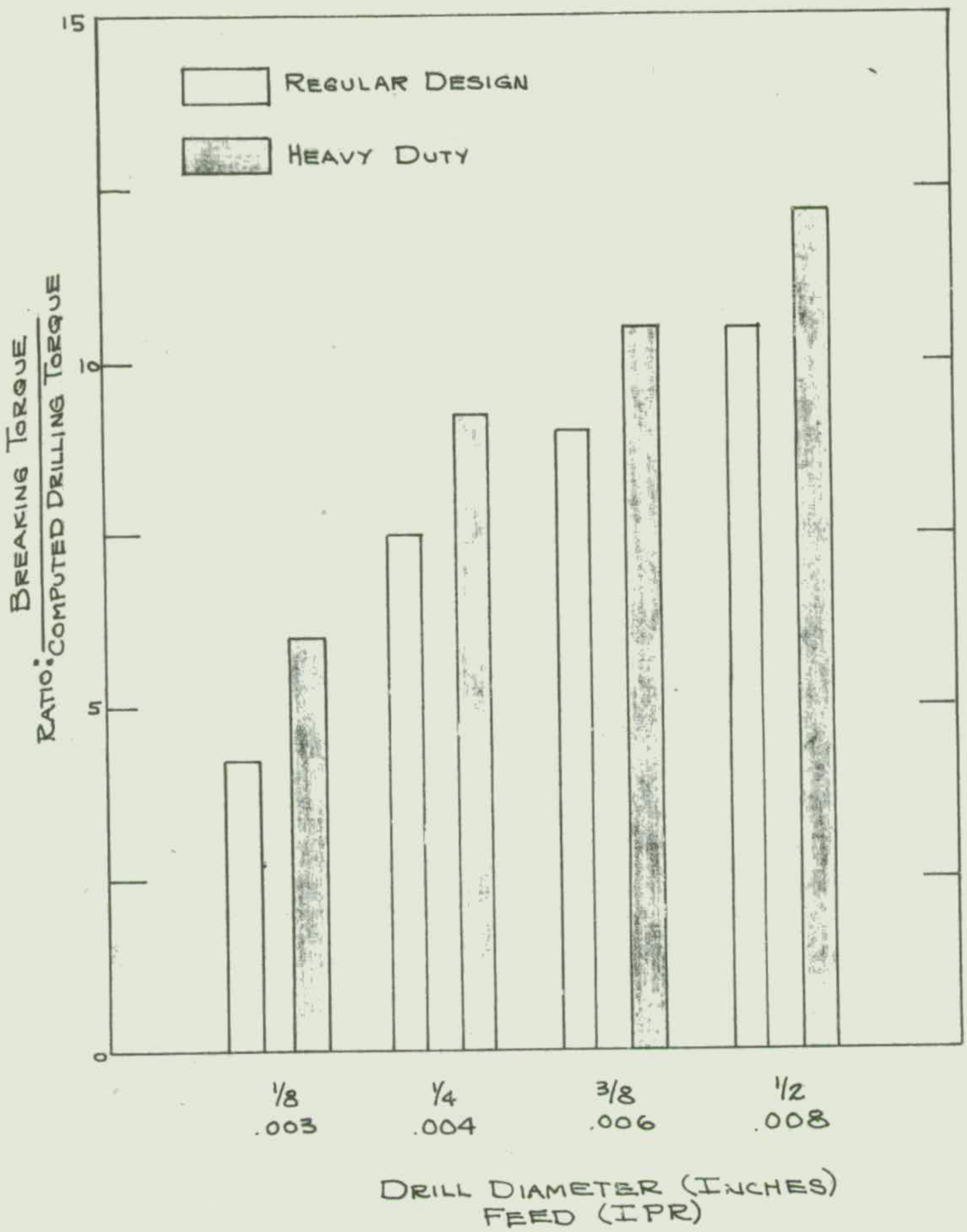


FIG. 2. Safety factors for regular and heavy duty drills

1. BOBER, PAUL

2. EIGHT WAYS TO KILL A DRILL AND METHODS TO PREVENT IT

3. MACHINE AND TOOL BLUE BOOK, May 1967, pp. 126-131

4. Eight popular drill styles, up to ½ inch diameter, and their uses are discussed along with eight factors that "kill" a drill point and what to do to prevent it. Modifications of drill points for special conditions are discussed.

   The eight common drill types and their uses are:

   1) General purpose - high production jobs except those that present problems of materials or set-up.

   2) Heavy duty - for jobs requiring maximum rigidity.

   3) Fast helix - used in non-ferrous materials such as aluminum or magnesium.

   4) Slow-helix - used in bakelite, molded plastics, brass and hard rubber.

   5) Bright-helix - have the same construction as general purpose drills except for the additional treatment.

   6) Super-cobalt - for tough drilling applications such as work-hardening stainless steel, chrome-nickel alloy steels and exotic space age materials.

   7) Sturdy-length utility drills - used with hand or breast drills and for portable electric drilling applications.

   8) Screw machine drills - overall length and twist lengths are proportioned as to flute contour, helix angle and web thickness for ease of penetration and chip removal.

   The eight possible types of drill failure and the probable causes are:

Type of Failure	Cause
Outer corners break down	Cutting speed too high for material. No cutting compound at drill point. Flutes clogged.
Cutting edges chip	The feed is too high or the clearance angle too large.

Type of Failure	Cause
Margin chips or the drill breaks	Oversize drill bushing. Point improperly ground. Feed too large or spring of backlash in drill press or work. Dull drill or flutes clogged.
Drill splits up the center	Lip clearance too small or feed too large.
Drill will not enter	Drill is dull, lip clearance too small or web too thick.
Rough hole	Improperly ground point. Improper cutting compound. Feed too high or fixture not rigid.
Oversize hole	Unequal angle or length of cutting edges or both. Loose spindle.
Unequal chips from each flute	Improperly ground point.

To reduce the required thrust force on a drill it is recommended that the web be thinned by a method such as the split point method. By sharpening a drill with primary and secondary point angles the life of a drill may be extended.

1. DAGNELL, J.

2. MACHINABILITY TEST BY A DRILLING METHOD

3. CIRP, 1967, Vol. 15, No. 4, pp. 301-308

4. This paper describes a short-time procedure to determine the wearing effect of a material on a cutting edge. The procedure is a drilling test utilizing a constant feed force. It is possible to determine the order between various grades of aluminum, brass, bronze, cast iron and steel.

The test involves using a special flat drill (Fig. 1), a constant feed force and a pilot hole drilled in a specimen to eliminate the effects of the chisel edge.

The total depth of the hole is divided into a number of equal distances (unit lengths). As the drill proceeds into the workpiece, increasing wear of the cutting edges causes a decrease in the penetration rate. The time required to drill each unit length is recorded and is plotted vs. the unit length number. The slope of the resulting curve is the wear index L. This is shown in Fig. 2.

$$L = \frac{\Delta\tau}{nl}\,\frac{l}{c}$$

L = wear index
$\Delta\tau$ = time difference in milliseconds for n unit lengths
n = number of unit lengths
l = unit length
c = constant (=1)

The wear indexes of nine non-ferrous metals and for four grades of cast iron are shown in Figs. 3 and 4 respectively.

The constant feed-force method provides information on the wearing effect of a material on a cutting edge. When compared with milling and turning it shows the greatest selectivity and the results are reproducible. The test is simple, reliable, can be adapted for testing different types of materials and requires only a small amount of material.

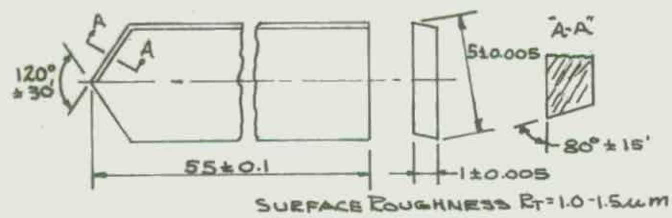


FIG. 1. Drill used in the experiments

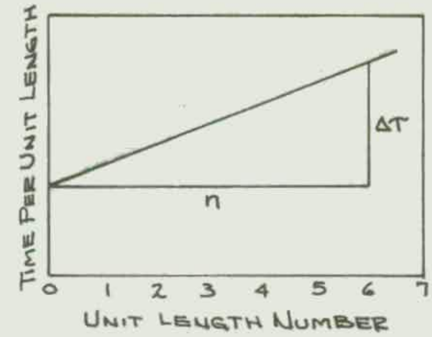


FIG. 2. Time per unit length versus unit length number

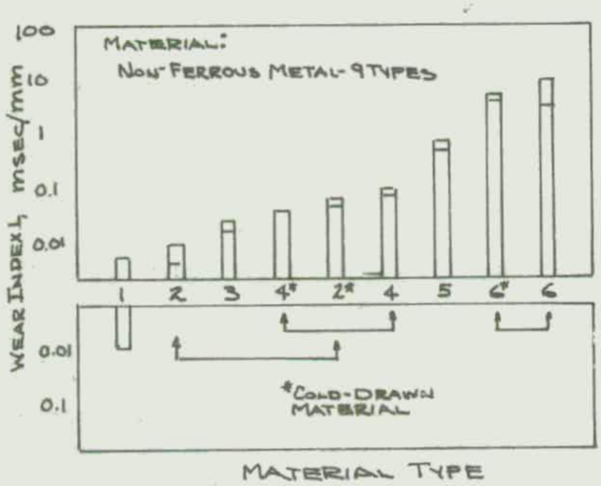


FIG. 3. Wear index for nine non-ferrous metals

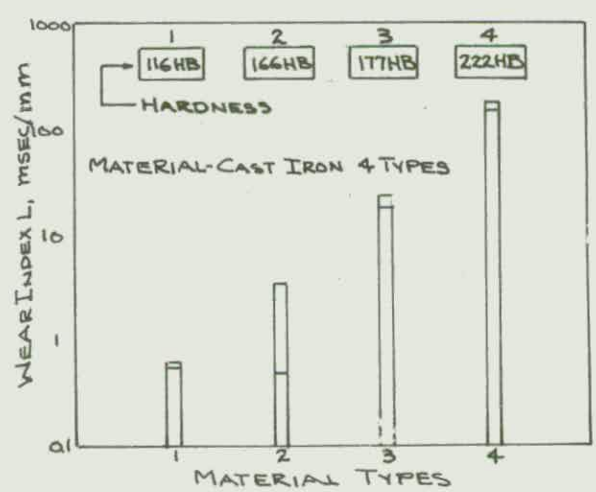


FIG. 4. Wear index for four types of cast iron

1. VENKATARAMAN, R. and KOENIGSBERGER, F.

2. SOME ASPECTS OF DRILLING ULTRA-HIGH-STRENGTH STEELS

3. "ADVANCES IN MACHINE TOOL DESIGN AND RESEARCH" 1967. pp. 893-921

4. The authors conducted an investigation into the drilling of steels having an ultimate tensile strength of 200,000 to 260,000 psi.

   To study the effect of lip geometry, they used a special drill that starts as a rectangular blade which allows various cutting angles to be incorporated. The special blade is shown with a standard drill.

   For the cutting tests with the special drills, the point angle was varied between 110-150 deg., apparent parallel rake angles, of 5, 10 and 15 deg. and apparent clearance angles of 4, 5, 6, 7 and 8 deg. were used.

   It was determined that the special drills having an apparent parallel rake angle = 15 deg. and a point angle of 130 deg. gave the best results as far as the lowest forces and chip formation were concerned.

   When drilling with a pilot in the test piece to eliminate the effect of the chisel edge, the apparent clearance angle had no appreciable effect. When the pilot hole was not used, a clearance angle of 4 - 8 deg. was found to perform best.

   When drilling with carbide tipped twist drills having a point angle of 130 deg., a poor surface finish was obtained. When an apparent parallel rake angle of 15 deg. (with respect to the plane of brazing) was incorporated on the drill, the finish improved.

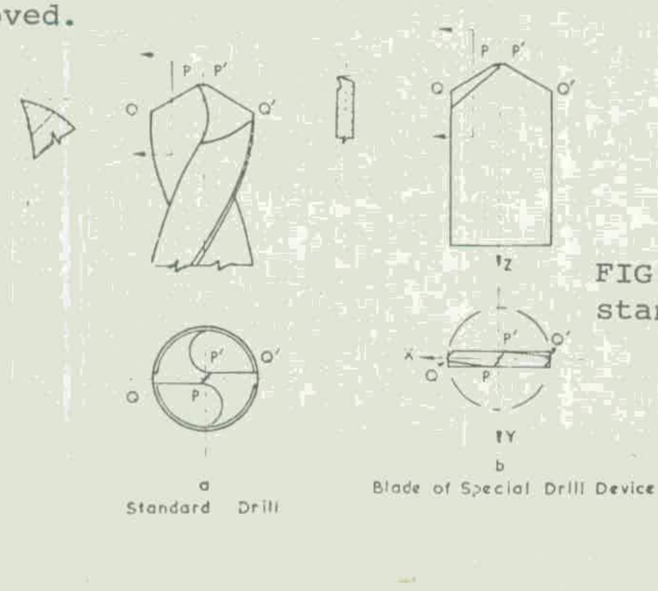


FIG. 1. Comparison of standard and special drill

1. MICHELETTI, G. F. and LEVI, R.

2. THE EFFECTS OF SEVERAL PARAMETERS ON TWIST DRILL PERFORMANCE

3. ADVANCES IN MACHINE TOOL DESIGN AND RESEARCH, 1967, pp. 863-877

4. Fourteen 12 mm diameter drills were inspected with the seven variables shown in Table 1 being considered for the tests. The average values and the standard error obtained are also given.

   The materials drilled were cast iron, drilled dry, and mild steel, drilled with mineral oil.

   All tests were run at 806 RPM with feed rates of 0.075, 0.125 and 0.20 mm/rev for the steel and feed rates of 0.125, 0.20 and 0.30 mm/rev for the cast iron.

   A least square multiple regression analysis was used to analyze the experimental data.

   Using this analysis it was found that the clearance angle affects the thrust when drilling steel at the maximum feed rate. The chisel edge angle has a greater effect on the thrust than on the torque with an increase of one degree in the angle causing a 5% decrease in thrust when drilling cast iron.

TABLE 1. Average values and standard errors of some dimensions measured on 14 drills, 12 mm dia.

Element	Variable	Average	Standard error
Relative lip height	x_1	0·025	0·019
Point angle	x_2	118°19′	44′
Lip clearance angle	x_3	14°25′	2°2′
Rake angle	x_4	26°52′	22′
Web offset	x_5	0·024	0·024
Chisel edge angle	x_6	118°6′	3°27′
Web thickness	x_7	1·727	0·049

1. BERA, S. and BHATTACHARYYA, A.

2. ON THE DETERMINATION OF TORQUE AND THRUST DURING DRILLING DUCTILE MATERIALS

3. ADVANCES IN MACHINE TOOL DESIGN AND RESEARCH, 1967, pp. 879-892

4. The authors have developed a method for determining the torque and thrust when drilling ductile materials. By applying the theory of wedge indentation, the effect of the extrusion process at the chisel edge has been accounted for. The torque may be computed by using the following equation:

$$T = \Big[0.37 \cdot s \cdot \sigma_u \cdot 6^{0.6\Delta}(r_2 - r_1) + \frac{k\left(r_2^{1-m} - r_1^{1-m}\right)}{s^n(1-m)}$$

$$- \frac{\tan\theta}{d \sin\rho}\left(r_2^2 - r_1^2\right) + \frac{d_c}{2}\cos\rho \cdot \log_e \frac{r_2}{r_1} + \frac{F(d-d_c)}{2\sin\rho}\Big] r_m$$

σ_u = ultimate tensile strength of material
Δ = % elongation
θ = helix angle
ρ = ½ point angle
d_c = diameter of chisel edge
d = drill diameter
F = specific frictional force at the cutting edge per unit length of contact length
k = intercept to be formed out separately from the respective graphs drawn for separate drill diameters
m = index of r_x: to be found as k
n = index of s to be found as k

ζ = $\frac{k}{r_x^m s^n}$ chip reduction coefficient

r_m = mean torque arm ($\frac{d+d_c}{2}$)

r_1 = radius of chisel edge
r_2 = outside radius of the drill

The thrust force was determined as the sum of three quantities:

$$P_{total} = P_{cutting} + P_{friction} + P_{chisel\ edge}$$

The total thrust force is expressed as:

$$P = 0.74 \cdot \sigma_u \cdot 6^{0.6\Delta} \cdot S \Big[\Big\{ (r_2 - r_1) + K \Big(\frac{r_2^{1-m} - r_1^{1-m}}{S^n (1-m)} \Big)$$

$$- \frac{\tan\theta}{d \sin\rho} (r_2^2 - r_1^2) + \frac{d_c}{2} \cos\rho \cdot \log_e \frac{r_2}{r_1} \Big\}$$

$$\cdot \tan \Big\{ \frac{\pi}{4} - \tan^{-1} \Big(\frac{\cos\gamma_e}{\zeta_e - \sin\gamma_e} \Big) \Big\} \sin\rho + 24.71\, d_c \Big] + N(d - d_c)$$

$K = 0.74\, \sigma_u^{0.6\Delta}$
γ_e = effective rake angle
ζ_e = chip reduction coefficient
N = specific normal force acting at the cutting edge in force per unit length of cutting edge

It was found that the thrust force is nearly one half of the total thrust force of a ductile material. A comparison of theoretically calculated torque and thrust and that determined experimentally shows that the derived equations are in close agreement with experimental results. This is shown in Figs. 1 and 2.

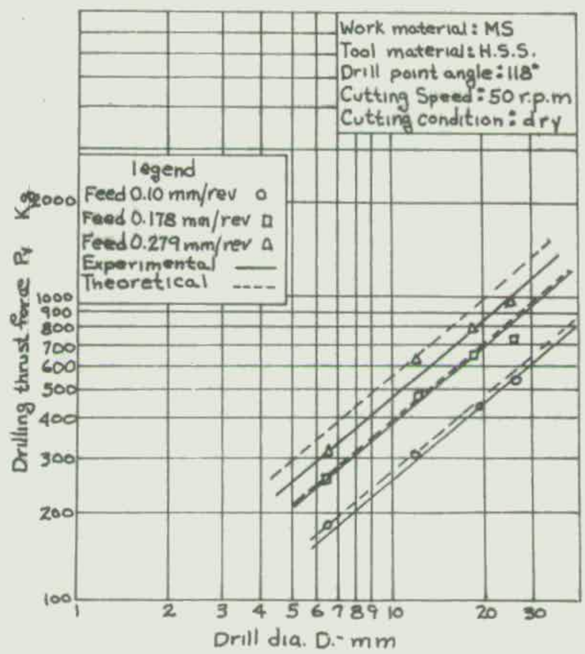


FIG. 1. Influence of drill diameter on thrust force

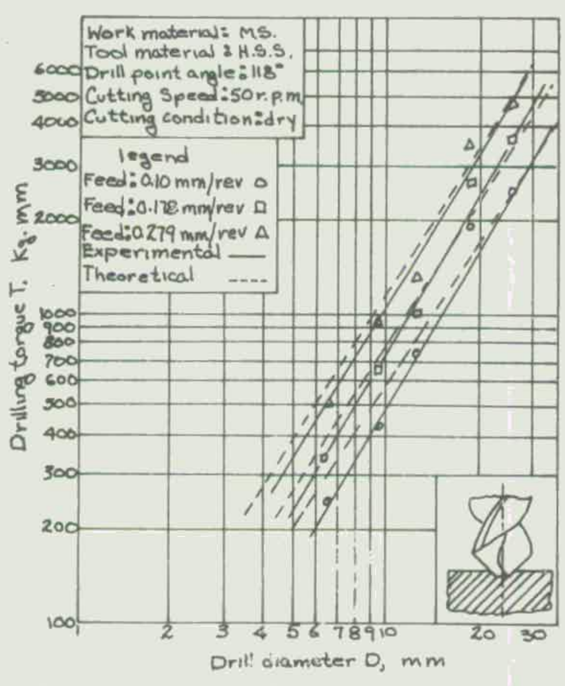


FIG. 2. Influence of drill diameter on torque

1. WALLER, C. E.

2. SOME SPECIAL EQUIPMENT AND TECHNIQUES DEVELOPED FOR THE PERFORMANCE TESTING OF TWIST DRILLS

3. ANNALS OF THE C.I.R.P., 1966, Vol. 13, pp. 367-373

4. This paper presents some special equipment and techniques that have been developed for performing drill life, flute clogging and toughness tests.

   The equipment for drill life testing performs the operation automatically. It has an automatic cycle and provides for indexing of the workpiece to any desired drilling location.

   Flute clogging was determined by mounting the workpiece on a torque dynamometer and observing any sharp increases in torque. The comparison of clogging performance is determined by the depth of hole drilled before flute clogging occurs.

   The toughness test is performed by starting a hole and then misaligning the hole relative to the drill axis. This misalignment is increased for each successive hole until the drill fractures.

   The misalignment as a percentage of hole diameter is the result compared between drills.

1. OXFORD, C. J., JR.

2. A REVIEW OF SOME RECENT DEVELOPMENTS IN THE DESIGN AND APPLICATION OF TWIST DRILLS

3. ADVANCES IN MACHINE TOOL DESIGN AND RESEARCH, 1967, pp. 845-861

4. The author reviews some of the developments of the twist drill during the past decade. These developments include:

   1) Flute modifications for chip breaking characteristics and increased torsional rigidity. Chip breaker drills generally require a greater amount of torque than standard drills and have a minimum feed below which they do not operate effectively. Three chip breaker drills by Crisp, Kallio and a standard U.S. design are shown in Figs. 1, 2 and 3.

      A self thinned heavy duty drill was developed by Oxford that increased drill rigidity by 30% to 50% over standard drills although it maintained the same web thickness.

   2) A method of determining the torsional rigidity of twist drills was developed by Oxford. It was found that the diameter of a circle that could be inscribed in a section of the drill normal to the axis was an indication of the drill rigidity (Fig. 4).

   3) A rail drill embodies the three criteria of increased drill rigidity; reduced flute length, reduced overall length, and increased flute cross section rigidity (Fig. 5).

   4) Fluid feed drills in which the cutting fluid is fed through integral passages in the drill lands. These drills deliver the cutting fluid in a mist or a pulsating stream. This type of drill allows increased penetration rates, longer tool life and the drilling of deeper holes.

   5) Numerical control machines require drills that do not need drill guide bushings. This can be found in the self-centering points or modified split point drills.

   6) High hardness high speed steel drills are most effective when they are kept short and rigid for drilling high strength, difficult-to-machine materials.

   7) Carbide tipped and solid carbide twist drills are most effective for drilling abrasive, low strength materials.

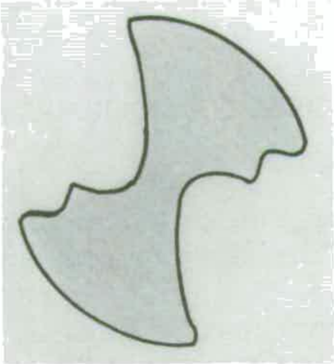


FIG. 1. Transverse section through the flutes of Crisp design chip breaker drill

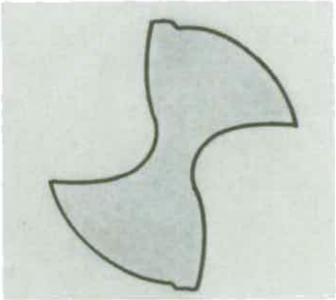


FIG. 2. Transverse section through flutes of Kallio design chip breaker drill

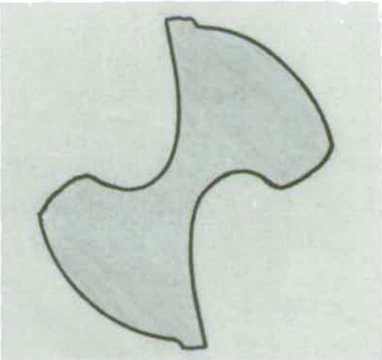


FIG. 3. Transverse section through flute of standard U.S. chip breaker drill

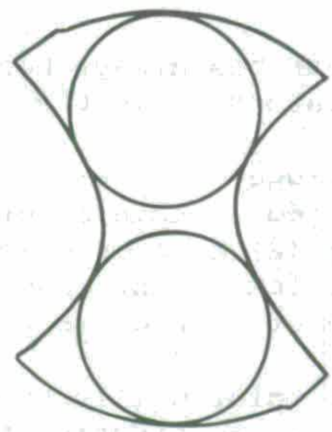


FIG. 4. Circles inscribed in transverse sections through flutes of heavy duty drill

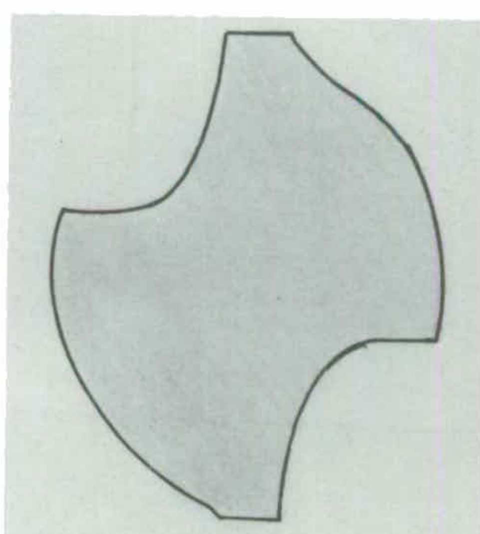


FIG. 5. Transverse section through flutes of rail drill

1. KIRSCHBAUM, R.

2. HOW TO MEASURE TOOL WEAR

3. AMERICAN MACHINIST, 1968, Feb. 26, pp. 105-106

4. Figuring out tool wear has always been an engineering challenge, whether in the laboratory or in the shop itself.

   Conventional chisel-edge drill with a standard point (unthinned web) should be measured in this order: (1) Wear on lips, back from edge on relief; (2) Wear on chisel edge-measured in the same way as the lips (extending from the center axis); and (3) Width and length of wear on margins.

   Thinned-web or split point drills should be measured in the same way as standard drills, considering the lips as primary and secondary.

   There are some equations for approximating drill life, but wide variations in types of drills, and even in drill lots, seriously limit their use. For example, one leading drill manufacturer reports that accurate drills don't last as long as less-accurate ones.

1. HOWE, R. E. (Editor)

2. PRODUCIBILITY/MACHINABILITY OF SPACE-AGE AND CONVENTIONAL MATERIALS

3. PUBLISHED BY SOCIETY OF MANUFACTURING ENGINEERS, Dearborn, Mich., 1968

4. With very few exceptions, drilling operations can be performed most economically on all space-age materials using suitable style of solid HSS drill.

   Most of the very high-strength materials require even more rigid drills; these are available from most manufacturers in the form of "heavy duty" or "cotter pin" style. This type of drill generally is a jobber's length but has an extra heavy web to provide greater rigidity. Web and point geometry are not standardized and vary considerably among drill manufacturers. The most common configuration, however, is a web having varying degrees of taper to the drill point which is ground to a 135 degree lip angle with a split or crankshaft point. These drills are usually supplied in either a standard (M-1, M-2, M-7) grade of HSS or a premium (T-15, M-33, M-36, etc.) "cobalt" grade.

   Fig. 1 illustrates drill geometry for split-point drills. Fig. 2 shows the results of an evaluation of various types of drills when drilling age-hardened Inconel 718. A comparison of drill life cost for drilling Inconel 718, 40 R_c, is shown in Fig. 3.

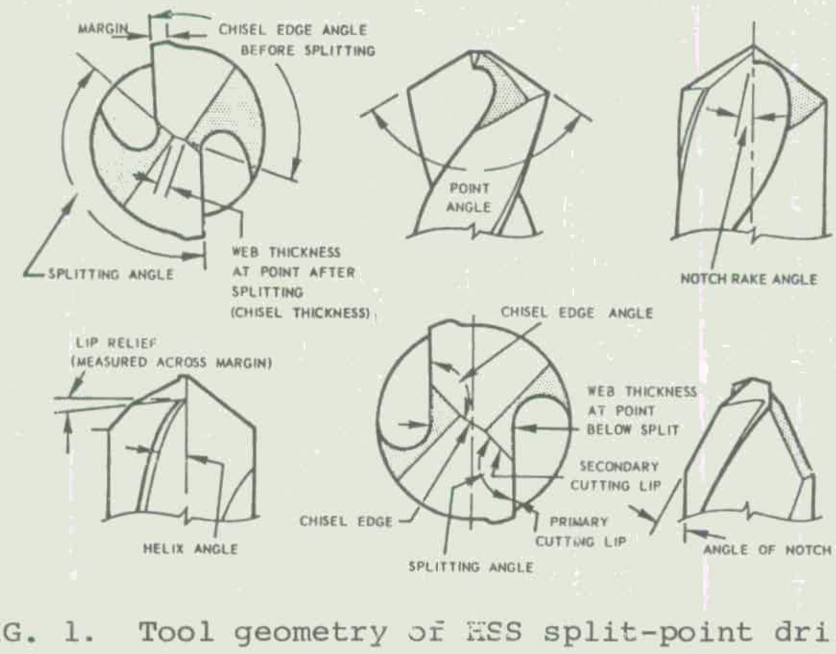


FIG. 1. Tool geometry of HSS split-point drills

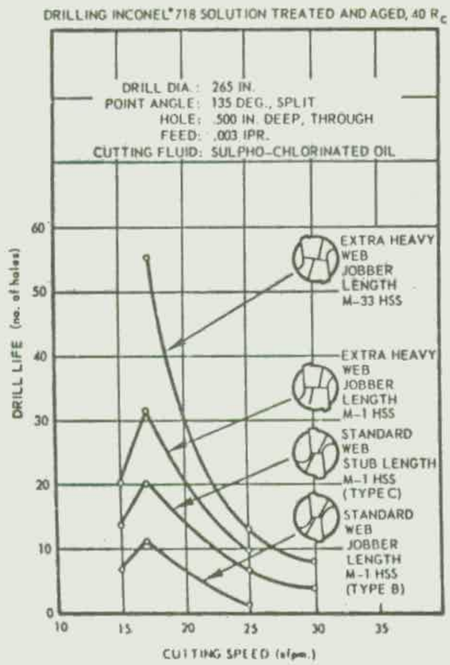
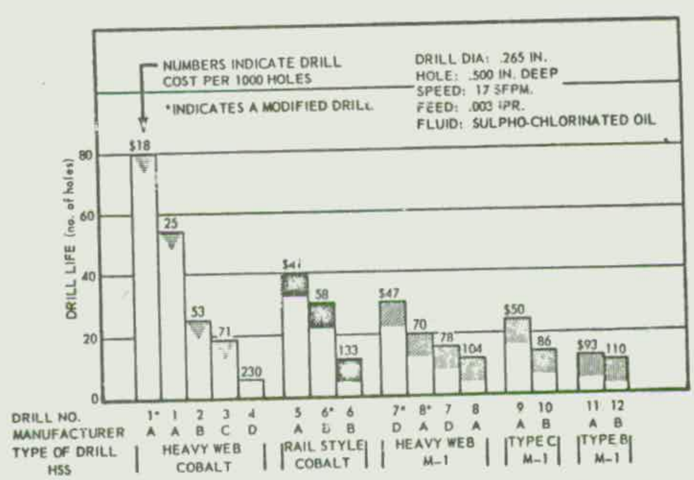


FIG. 2. Effect of drill geometry on drill life



Drill life and costs for drilling Inconel 718* 40 R_C.

FIG. 3. Drill life and costs for drilling Inconel 718 (40 R_C)

1. HÄUSER, K.

2. DIE FERTIGUNG VON WENDEL-(SPIRAL-) BOHRERN IN DEUTSCHLAND VOR 1890 (Production of Twist Drills Before 1890 in Germany)

3. WERKSTATT UND BETRIEB, 1968, Vol. 101, No. 10, pp. 639-642

4. Before 1865, twist drills were imported to Germany from the U.S.A., imported twist drills were disliked because of 1) higher price (½" dia., 6" long drill cost 1/10 thaler where 1 thaler is equivalent to 1 dollar); 2) competition with foundary workers.

   Finally, in 1867, twist drills were exhibited at Paris for the first time on the European continent. At that time Germany and Switzerland had already begun to produce twist drills. During that time the forgesmith behaved like a "king" in the factory, making all kinds of tools and performing the heat treatment. It was natural that these men wanted to prevent the purchase of twist drills because they hindered their status.

   The C. H. Bernhardt Firm in Sachsen was the first manufacturer of twist drills in Germany. As shown in the journal, "Der Maschinenbau" in 1869, twist drills were falsely translated as spiralbohrer into German. Since that time the name "spiralbohrer" grew popular, even though this translation was not correct. Even though the firm of J. G. Weissen Soehne in Baden-Wuettenberg began to manufacture twist drills in 1872, they stopped production in 1889 because of intense competion.

   The firms of George Meier, Baden, Gustav Jakoby, Leipzig, Gebr, Werner, Lennex, and at least three other firms in Germany conducted twist drills production in 1889. Until 1890, twist drills were produced by mutual cooperation using drill grinding machines, which were imported from the U.S.A. Later, these machines were constructed in Germany. After an economic crisis in Germany in the early 1900's, the price of twist drills changed.

   Many firms which were established at that time, approximately 1890, still exist at present and are operating.

1. BARASH, M.

2. TWO-DIAMETER DRILL HAS HIGH STRENGTH

3. MACHINERY, 1968, Vol. 75, April, pp. 192

4. Solid carbide drill, Soviet patent 195830, is used for producing very small holes in two steps. In the transition zone between the small diameter and the taper, the flute is formed so the core thickness of the small drill is equal to its diameter. This strengthens the drill.

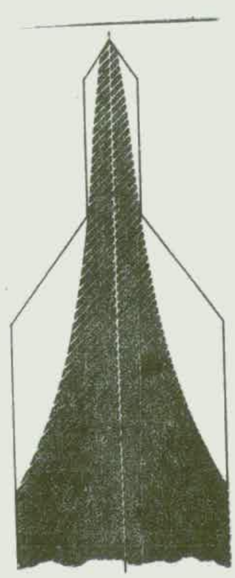


FIG. 1. Solid carbide drill

1. BARASH, M.

2. DRILLING TESTS USED TO MEASURE MACHINABILITY

3. MACHINERY, 1968, Vol. 75, Nr. 4, pp. 135-136

4. Relative machinability of materials can be quickly determined with a simple spade drilling test.

   Measuring the machinability of metals is a perennial problem. From time to time, new techniques are added to those already available. A very promising one is a simplified test developed at the Chalmers University of Technology in Sweden.

   In this test, a spade drill is employed to enlarge a drilled hole, using constant feed force. Since feed force is constant, the rate of axial progress slows down as the tool wears. If the depth to be drilled is divided into units of equal length, each successive unit requires more time to machine.

   The spade drilling machinability test has been run on steels, cast iron, copper and aluminum alloys, using tool steel and carbide spade drills. A remarkably low scatter of $\pm$ 5 percent is reported for the results.

   Merits of this test are good reproducibility, short duration, small amount of material needed, and greater sensitivity to variations in material quality than is the case for milling and turning tests. Although the test can only provide a relative index of machinability, it deserves serious consideration for adoption as one of the standard test techniques.

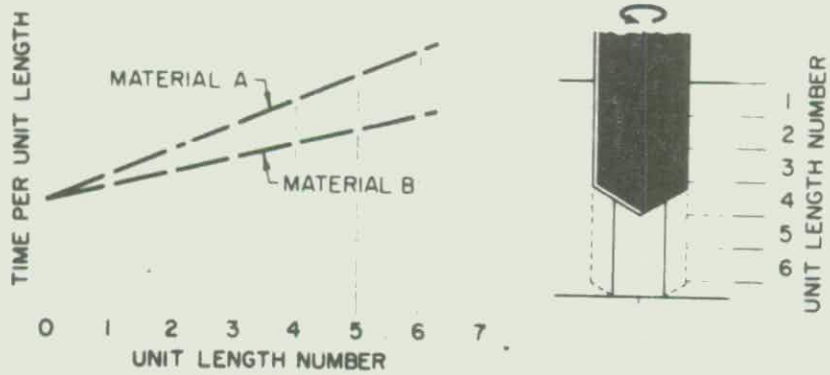


FIG. 1. Result of machinability test

1. WILLIAMS, R. L. and TRIGGER, K. J.

2. A PHOTOGRAPHIC METHOD OF INVESTIGATING CHIP FLOW IN TWO-FLUTE TWIST DRILLS

3. ASTME PAPER NO. MR68-505, 1968

4. A computer program was written and used to compute the helix angle, inclination angle, rake angle, effective rake angle and normal rake along the cutting edge.

   In studying the chip flow, the authors have determined:

   1. Drills that are accurately ground on the face to increase axial rake near the chisel edge produce better chip flow.

   2. A 30 degree secondary clearance on the flank, which produces a chisel edge angle of 125-130 degrees, and the procedure for grinding the face produces a notch in the flank into which the chip can egress. This lowers the drill thrust and stabilizes the drill during "steady state" drilling.

   3. In drilling Grade 48004 malleable iron the modified 20 degree constant helix produced less variation in thrust than the standard chisel edge drill. It is thought that this is due to the chisel edge chip having a place to egress and not building up between the drill and the bottom of the hole.

   4. In drill life tests, with a sharp increase in torque as the criterion of failure, the modified 20 degree helix proved superior to other drills with respect to torque, thrust, chip formation, tool life and hole size.

1. DeVRIES, M. F.

2. DRILL TEMPERATURE AS A DRILL PERFORMANCE CRITERION

3. ASTME PAPER NO. MR68-193, 1968

4. The five methods that are generally employed in measuring temperatures in drilling are discussed. The five methods are: 1) Tool-work thermocouple, 2) Methods using standard thermocouples, 3) Thermal sensitive points, 4) Indirect temperature measurement, and 5) Garter spring thermocouple.

The tool-work thermocouple method utilizes the junction formed between the drill and the workpiece. This method measures the average temperature of the chisel edge point, the cutting edges and drill flutes with the result that the temperature obtained is not the maximum temperature of the cutting edge.

The standard thermocouple method uses thermocouples inserted into the drill or workpiece. This method allows local temperatures to be determined and three dimensional temperature fields to be established.

Thermal sensitive points are quick and easy to use although local temperatures are difficult to discern and time-temperature relationships cannot be obtained.

The indirect temperature measurement techniques can be used to determine the energy generated in the cutting zones although this does not give the temperature at the cutting surfaces or a temperature distribution on the cutting surfaces.

Either a calorimetric technique or calculations using force, speed and power measurements are used in the indirect temperature measurement technique.

The Garter spring thermocouple technique, Fig. 1, was evaluated by two tests. The first test consisted of determining whether consistent results could be obtained from thermocouples inserted in identical oil hole drills. The results were found to be essentially the same.

The second test compared the results from the Garter Spring method with the tool-work thermocouple method. The results indicate that the Garter Spring and tool-work methods have a

similar correlation of temperature and cutting speed, as shown in Fig. 2. There is a difference between the temperatures obtained with both methods. This is due to the fact that the tool work method measures an average temperature on the cutting edge while the thermocouple of the Garter Spring method measures the temperature on the drill flank.

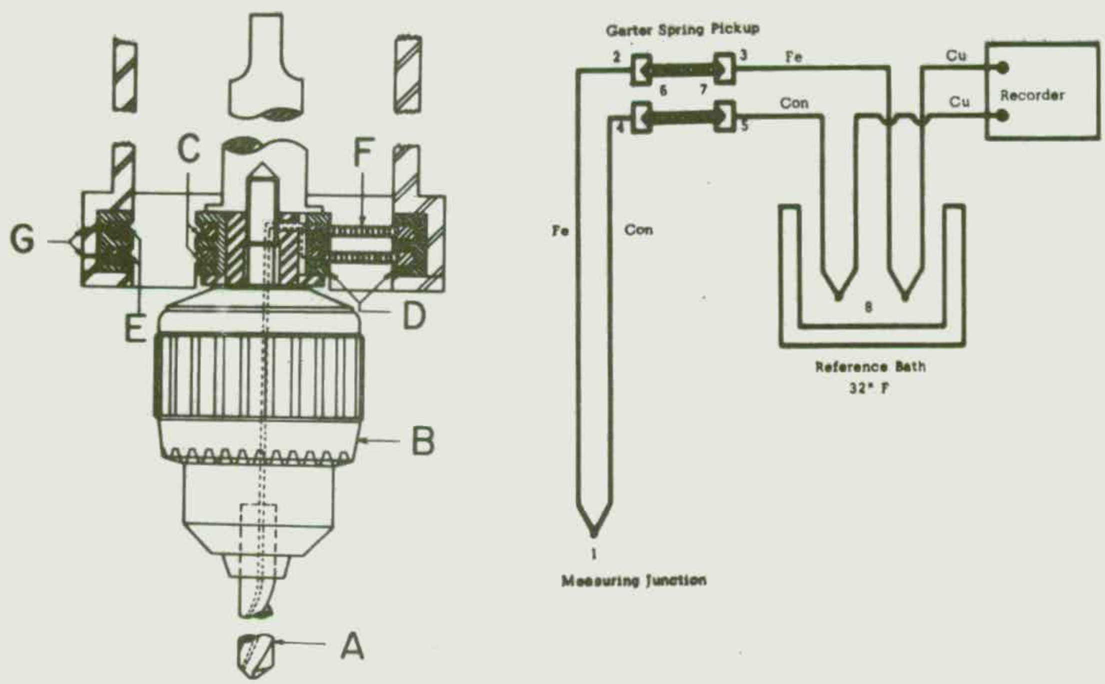


FIG. 1. Garter spring pickup

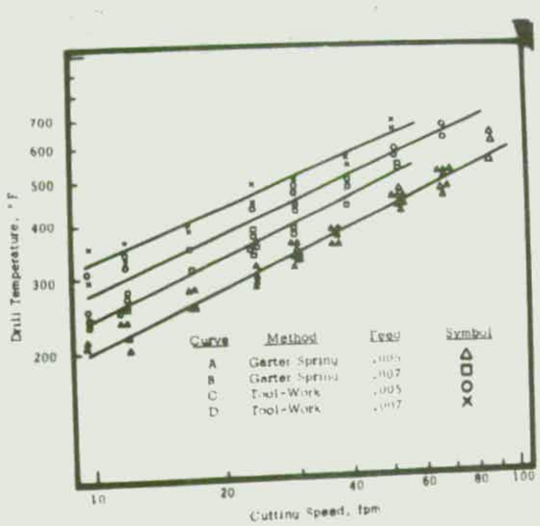


FIG. 2. Comparison of tool-work and garter-spring thermocouple methods for determining drill temperatures

1. DeVRIES, M. F., SAKENA, U. K., WU, S. M.

2. TEMPERATURE DISTRIBUTIONS IN DRILLING

3. TRANSACTIONS OF THE ASME, 1968, pp. 231-238

4. Utilizing modifications of Tsueda's and Loewen and Shaw's equations, the authors have obtained temperature distributions along the cutting edge and flank face.

   A typical temperature distribution along the cutting edge is shown in Fig. 1. The dimension is measured along the flank face beginning at and perpendicular to the cutting edge.

   It is also shown that cutting speed has a greater influence on temperature than feed rate. This is demonstrated in Figs. 2 and 3 which show that an increase in cutting speed of about 80% increased temperature about 40% while increasing the feed rate by 90% only increased the cutting edge temperature 10%.

   The effects of cutting time on cutting edge temperature are also shown in Fig. 4. There is an initial sharp increase in temperature followed by an almost linear increase after three minutes.

   The effect of workpiece volume on drill flank temperature distributions was investigated and it was found that the temperature increased as the workpiece volume decreased. This relationship is shown in Fig. 5.

   By drilling into a test piece that contained a pilot hole, the effect of the energy generated by the chisel edge on the drill flank temperature distribution was determined. The temperatures obtained when drilling a workpiece with a pilot hole were lower than those obtained when drilling without the pilot hole.

   The analytical and experimental results compared favorably except near the chisel edge and the drill periphery. The analytical results were lower than the experimental near the chisel edge. This is explained as being partly due to the fact that the energy generated by the chisel edge was not included in the analytical solution.

   No definite explanation is given for the temperature difference at the drill periphery.

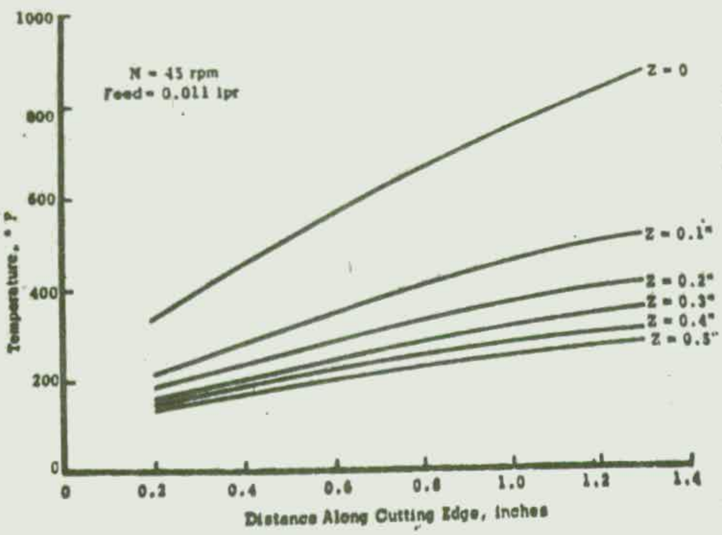


FIG. 1. Theoretical temperature distribution along and parallel to the cutting edge

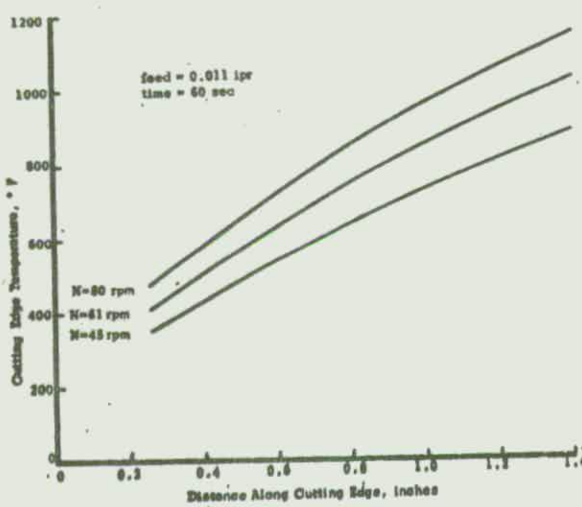


FIG. 2. Effect of cutting speed on cutting edge temperature

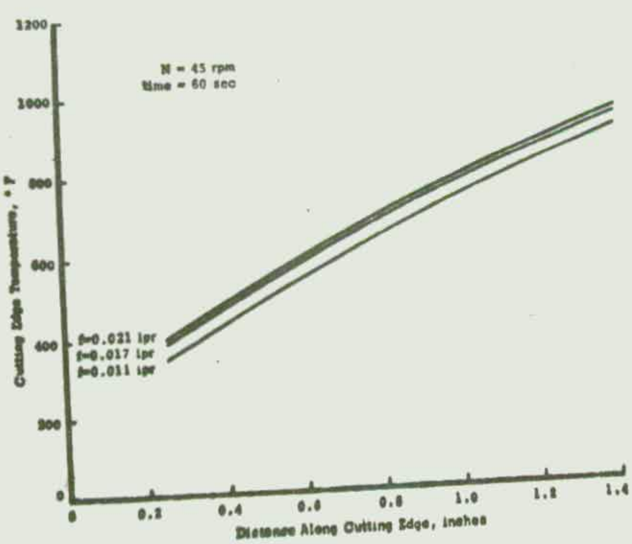


FIG. 3. Effects of feed rate on cutting edge temperature

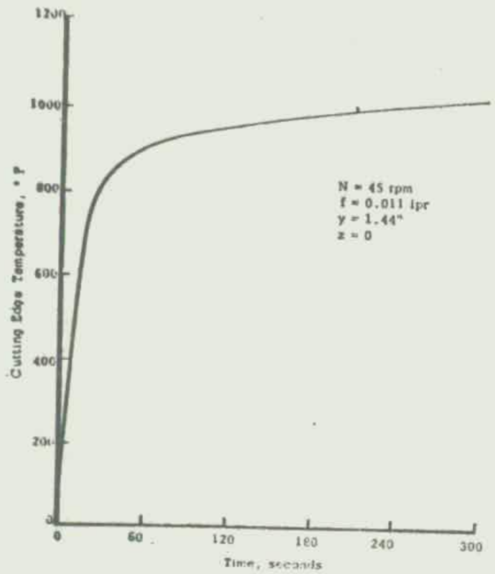


FIG. 4. Relationship between cutting time and cutting edge temperature

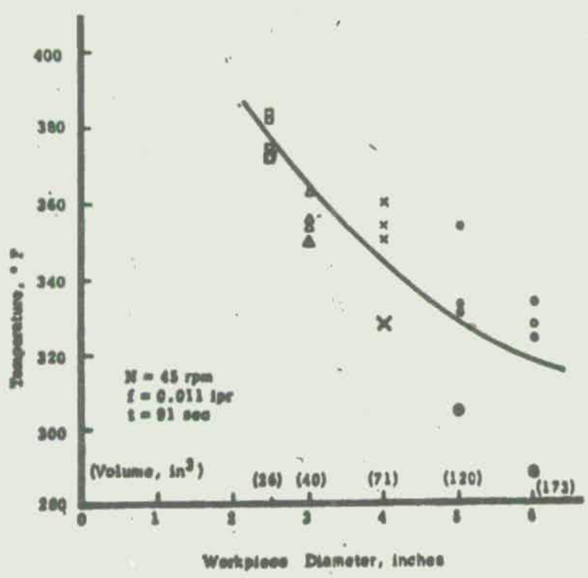


FIG. 5. Influence of workpiece volume on experimental drill flank temperature

1. RYZHKIN, A. A.

2. MONOLITHIC CEMENTED CARBIDE DRILLS FOR HEAT-RESISTING STEELS

3. MACHINES & TOOLING, Vol. 39, No. 6, pp. 37-39, 1968

4. Monolithic pressed shank VK15M cemented carbide drills were used to drill austenitic heat resistant steels.

   An optimum drill geometry was established with the point angle being 125-127 degrees and a clearance angle 8 to 10 degrees.

   It is stressed that the cutting edge eccentricity should be kept at a minimum. The radial eccentricity of the drill point should be less than 0.05 mm (0.002 in.) and the cutting edges must have sufficient reverse taper. The effect of the reverse taper and radial eccentricity on drill life is shown in Figs. 1 and 2.

   A comparison of drill life between the carbide drills and R-18 HSS is shown in Table 1. Although the carbide drills can be run at higher speeds their lower strength limits the feed rate that they can be used at.

   It was found that the cutting speed had an effect on the torque and thrust force. With an increasing feed rate the minimum values for torque and thrust move towards the lower cutting speeds, Fig. 3.

   The torque and thrust relationships were established as

   $$M_t = 134\, d^{1.18}\, s^{0.49}\, v^{-0.13}\ \text{Kgf mm}$$

   $$P_{ax} = 126\, d^{0.71}\, s^{0.41}\, v^{-0.18}\ \text{Kgf}$$

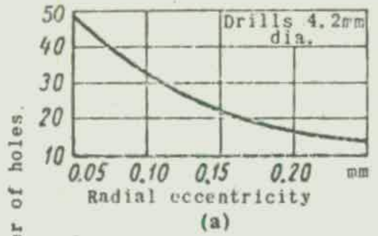


FIG. 1. Effect of eccentricity on drill life

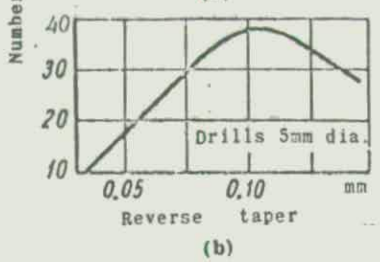


FIG. 2. Effect of reverse taper on drill life

Drill diameter (mm)	Feed rate (mm/rev)	Cutting speed (m/min)	Drill life (min)	
			R18 steel	VK15M carbide
3.2	0.033	9.5 13.8 18.3	— — —	71 23 10
4.1	0.043	8.7 12.2 17.7	— 12 3	135 49 16
5.0	0.058	10.4 14.8 21.5	— 5 1.7	92 33 10.5

TABLE 1

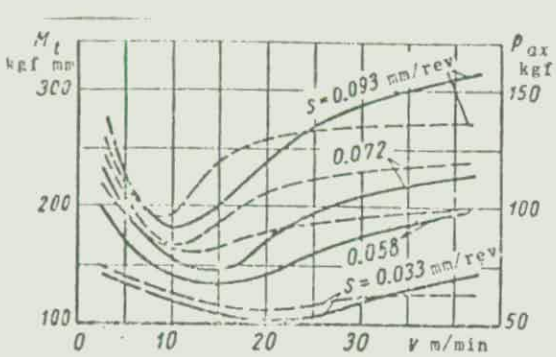


FIG. 4. Effect of cutting speed on torque

1. LIVSHITS, A. L. and LIVSHITS, V. L.

2. APPROXIMATING STRESSES IN DRILLS

3. MACHINES & TOOLING, 1968, Vol. 39, No. 4, pp. 41-42

4. In order to analyze the stressed state of a drill as a straight or naturally coiled rod, it is necessary to determine a stress function F that satisfies Poisson's equation and having zero value on the cross section profile. Known formulas can then be used to calculate the shear stresses and torques.

In the drill cross-section shown in Fig. 1, the web thickness is $m = 0.6a$, the width of the drill tooth is $n = 0.12a$ and $R_1 = 1.514a$ 1.514a.

In bipolar coordinates α and β the equations for the profile sections are:

for AB and DC

$$\beta = \pm \frac{\pi}{2}$$

for BC and AD

$$\alpha = \pm 0.62a$$

Poisson's equation in bipolar coordinates, relative to stress function ϕ is

$$\frac{\partial^2 \phi}{\partial \alpha^2} + \frac{\partial^2 \phi}{\partial \beta^2} = -\frac{2}{g^2} \cdot G \cdot \theta$$

while the stresses and torque M are

$$\tau_{\alpha z} = g \frac{\partial \phi}{\partial \beta}; \qquad \tau_{\beta z} = g \cdot \frac{\partial \phi}{\partial \alpha}$$

$$M = 2 \iint \frac{\phi(\alpha, \beta)}{g^2} \cdot d\alpha \cdot d\beta$$

where $g = \dfrac{\cosh \alpha + \cos \beta}{\alpha}$

$\tau_{\alpha z}$ = projection of the shear stress on a tangent to the line β = const., passing through the given point.

$\tau_{\beta z}$ = projection of the shear stress on a normal to the line β = const.,

G = shear modulus

θ = relative torsion angle

Since the section is symmetrical about the X and Y axes, the stress function is

$$\phi = \frac{1}{2} G\theta \alpha^2 \left(\sum_{m=1,3,5} C_m \, ch \, m\alpha \cos m\beta + \frac{2\cos\beta}{ch\alpha + \cos\beta} \right)$$

where C_m is the approximating series coefficient.

The results of the problem after four approximations is shown in Table 1.

The resistance moment M, curves 1 to 3, and the torsion angle Θ, curves 4 to 6, are shown in Fig. 2.

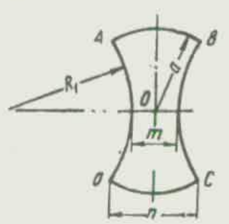


FIG. 1. Drill cross-section

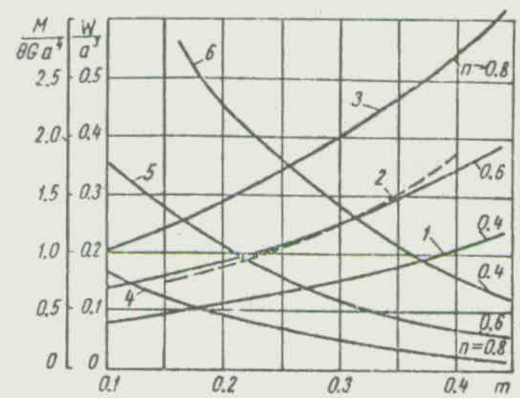


FIG. 2. Resistance moment and torsion angle

TABLE 1. Four approximations obtained

Combination points with α =0.62	Series coefficients	$\frac{\tau}{G\theta a}$ at point 1	$\frac{\tau}{G\theta a}$ at point 2	$\frac{M}{G\theta a^4}$
$\beta_1 = 0$	$C_1 = -0.762$	0.619	0.856	0.237
$\beta_1 = 0$ $\beta_2 = 0.91$	$C_1 = -0.082367$ $C_2 = 0.02373$	0.553	0.66	0.239
$\beta_1 = 0$ $\beta_2 = 0.6$ $\beta_3 = 1.18$	$C_1 = -0.82226$ $C_2 = 0.02925$ $C_3 = -0.001773$	0.54	0.705	0.2394
$\beta_1 = 0$ $\beta_2 = 0.43$ $\beta_3 = 0.91$ $\beta_4 = 1.3$	$C_1 = -0.82134$ $C_2 = 0.02851$ $C_3 = -0.002642$ $C_4 = 0.000265$	0.539	0.69	0.2396

1. DUBROV, YU.S., ET AL

2. SURFACE FINISH USING PLASTIC-SHANKED DRILLS

3. MACHINES & TOOLING, 1968, Vol. 39, No. 8, pp. 39

4. Improvements in drill life and the surface finish of the drilled hole are obtained when using drills with plastic shanks.

The drills tested were high speed steel (R18), 6 mm in diameter, with a 26 degree helix angle, 12 degree clearance angle with a 118 degree point angle.

Three grades of steel were tested and one grade of cast iron.

A comparison of the surface finish obtained with regular and plastic shanked drills is shown in Fig. 1.

By completing an electrical circuit between the plastic shanked drill, workpiece and machine, the roughness of the surface was increased as shown in Fig. 1-d.

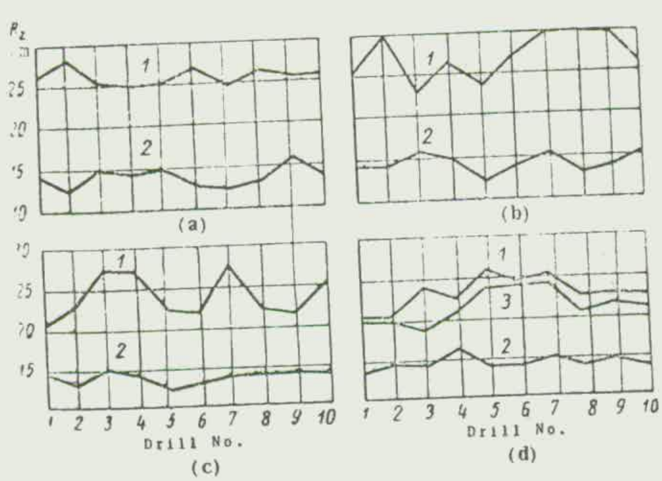


FIG. 1. Surface finish in drilling
1) conventional drill
2) drill with plastics shank, open circuit
3) Drill with plastics shank, closed circuit

1. KOTLIKOVA, A. L.

2. THE LIFE OF HIGH SPEED STEEL DRILLS IN DRILLING GREY IRON

3. RUSSIAN ENGINEERING JOURNAL, Vol. XLVIII, 1968, No. 1, pp. 79-81

4. In conducting the dri ll life experiments the author found the tool life was not given over the entire range of cutting speeds, V, by the relation $v = C_V/T^m$. This relationship was accurate between the cutting speeds of .26 to 45 in/min but not below the lower limit. By using a Fourier series the tool life for the full range of cutting speed was obtained (Fig. 1).

The author utilizes a vT, number of holes drilled vs v, cutting speed to determine optimum cutting speed. This is shown by Fig. 2.

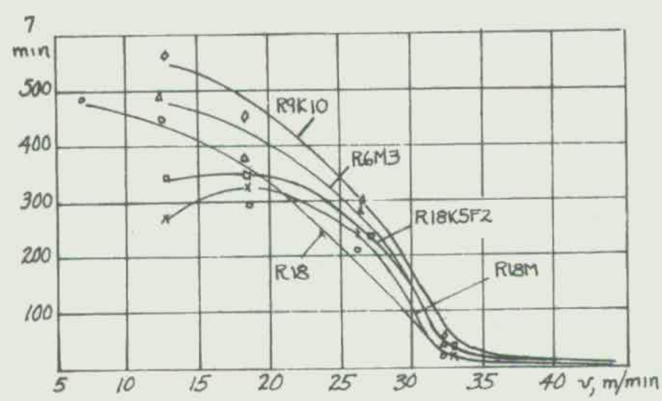


FIG. 1. Tool life versus cutting speed

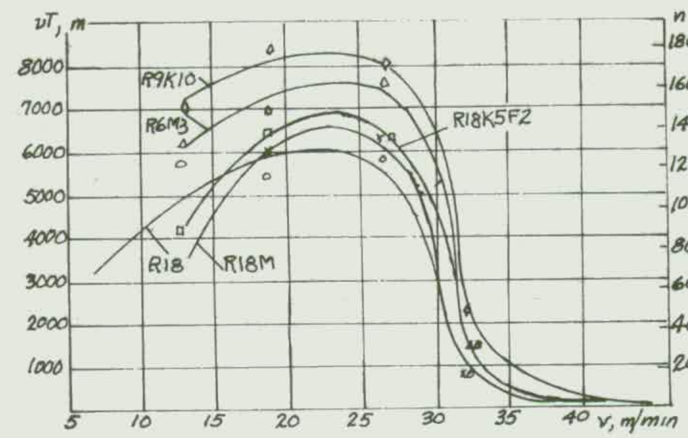


FIG. 2. Relationship of number of holes drilled to cutting speed

1. VENKATARAMAN, R. and PARKER, J.

2. DEVELOPMENT OF A THREE DIMENSIONAL CUTTING EDGE GEOMETRY FOR A DRILL

3. ANNALS OF C.I.R.P., 1968, Vol. 16, pp. 277-289

4. A special drill was designed so that any desired rake face geometry can be incorporated. The cutting action of the lips of the special drill is similar to that of any ordinary twist drill (Fig. 1).

   A three dimensional mathematical model and computer program was written for determining the variation of the drill geometry. Expressions were developed for the normal rake angle, Y_n velocity rake angle, Y_v parallel rake angle, Y_p inclination angle i, normal clearance angle α_n, velocity clearance α_v, and parallel clearance angle α_p, and these were calculated for known values of drill radius L, web thickness t, point angle ε, apparent parallel rake angle Y_{ap}, and apparent parallel clearance angle α_{ap}.

   The theoretical values and those obtained from the actual drill compare closely (Fig. 2).

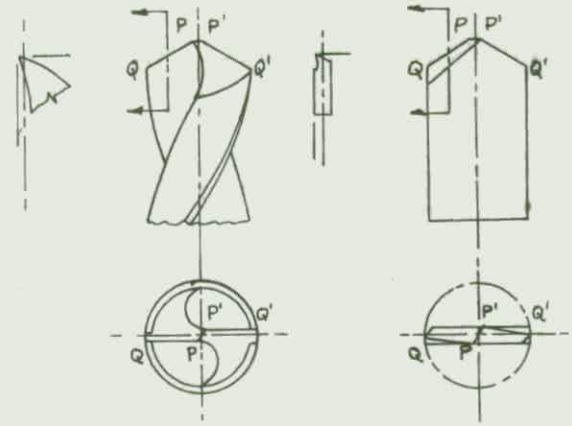


FIG. 1. Comparison of standard and special drill

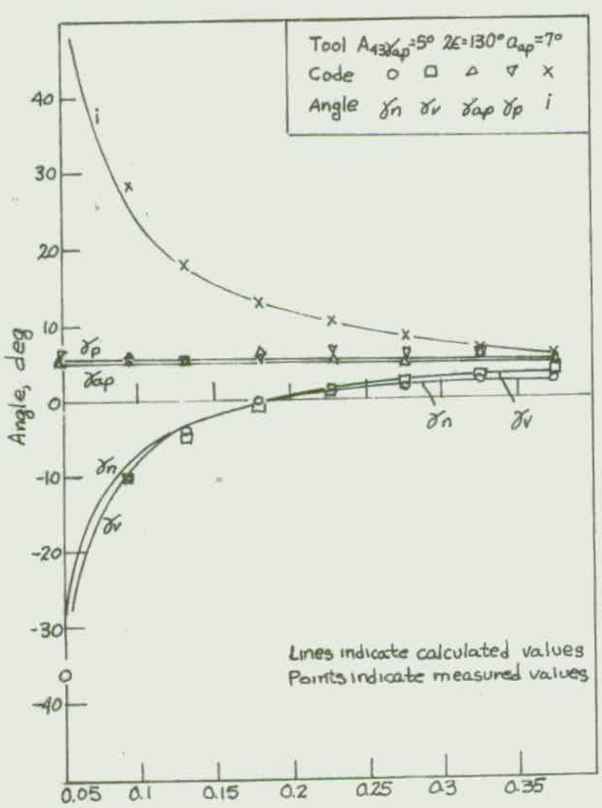


FIG. 2. Calculated and measured rake angles on the special drill

1. ANONYMOUS

2. FOUR FACET DRILL POINT GEOMETRY FOR CAST IRON

3. MACHINERY, 1969, Vol. 76, No. 2, pp. 125

4. Using a modified four facet drill point geometry, Soviet researchers have found that this drill geometry is 30 percent more efficient and lasts 5 times longer than standard drills in drilling cast iron.

   This drill has a 90 degree point angle, 16 degree lip relief angle, 44 degree clearance angle at the outer corner, a chisel edge angle of 135 degrees and the intersection of the lip relief and clearance surfaces is 8 degrees. The drill is shown in Fig. 1.

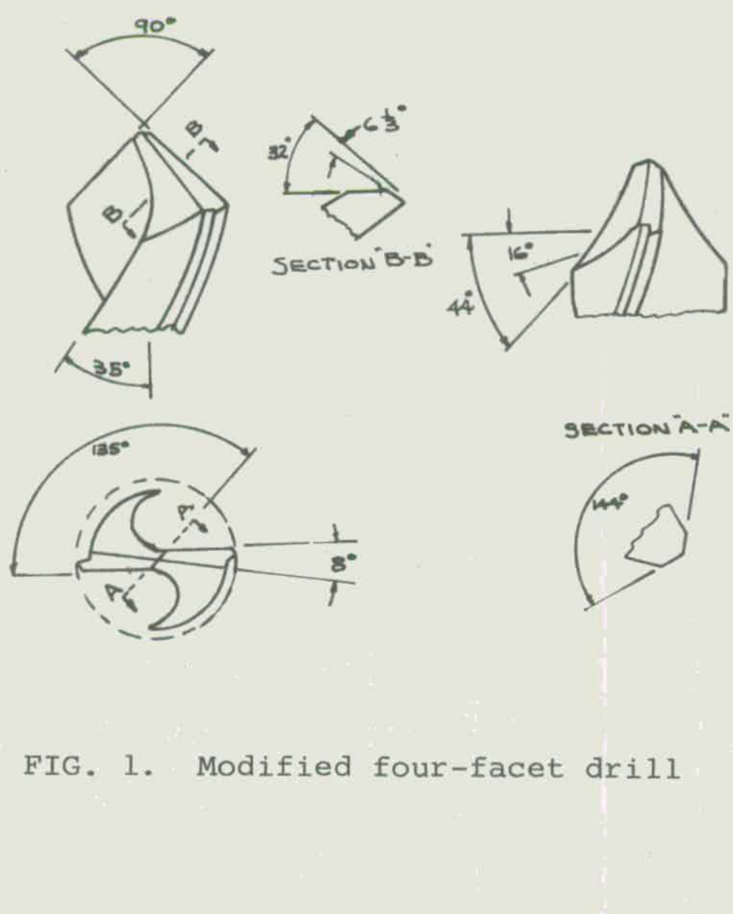


FIG. 1. Modified four-facet drill

1. POND, J. B.

2. BETTER TWIST DRILLS: MORE HOLES FOR LESS MONEY

3. MACHINERY, 1969, January, pp. 107-108

4. One of the most important developments in drilling technology during the past few years has been the application of twist drills sharpened by the radial lip grind.

   Another way to improve twist drilling productivity is to pump coolant through the tool. When coolant is delivered through the tool to the bottom of the hole, it dissipates heat more effectively at the point of cut and helps to flush out chips (Fig. 1). Tool life is better, hole finishes are improved and closer tolerances can be held - advantages that may make coolant-feeding drills desirable, despite their high price. (Typically, a coolant-feeding twist drill costs 2.5 times more than a standard twist drill of the same size. Coolant pressure usually ranges from 80 to 150 psi - well below the 600 to 700 psi pressure required for gun drilling.

   Newly developed four-facet point consists of flat primary relief and secondary clearance on each flute, with the four planes converging at the point. The cutting lips are then ground on the helix with a negative angle to achieve what is described as a "lathe tool geometry".

   One manufacturer who drills hundreds of thousands of holes per year reports that radial lip, coolant feeding drills give him five times more holes between sharpening than conventional drills.

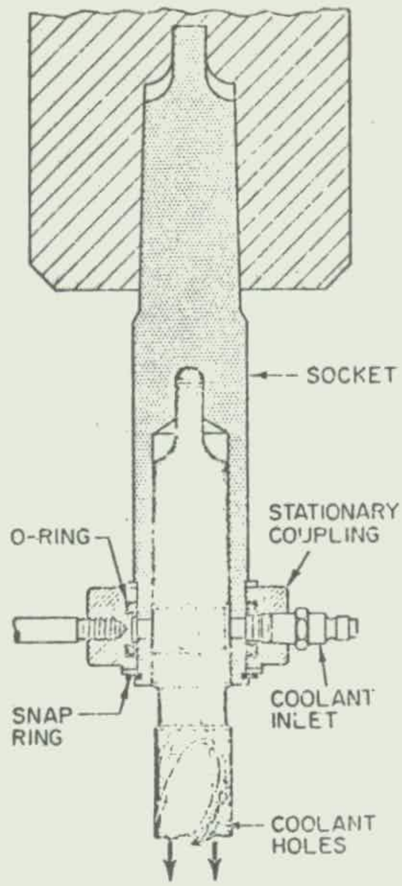


FIG. 1. Coolant-feeding drill

1. WILLIAMS, R. L.

2. NEW POINT GEOMETRY TRIPLES TWIST DRILL LIFE

3. MACHINERY, 1969, Vol. 75, No. 8, pp. 116-117

4. By grinding drills so that they have a constant helix angle of 20 degrees, it was found that drill life was improved by about 300 percent over standard drills when drilling malleable iron.

   With the special drill point grind the thrust force is reduced as well as the thrust variation in a given hole. It is thought that this is due to the better chip flow of the modified drills.

TABLE 1—DRILL POINT GEOMETRY

HELIX ANGLE (degrees)	CHISEL EDGE ANGLE (degrees)	CHISEL EDGE LENGTH (inch)
30.5 (standard)	125	0.0672
5 (constant)	125	0.0605
10 (constant)	127	0.0596
15 (constant)	125	0.0605
20 (constant)	126	0.0605
25 (constant)	125	0.0588

TABLE 2—DRILL LIFE

HELIX ANGLE (degrees)	NUMBER OF HOLES
30.5 (standard)	175
5 (constant)	19
10 (constant)	91
15 (constant)	131
20 (constant)	515
25 (constant)	163

TABLE 3—TORQUE AND THRUST

POINT GEOMETRY*	HOLE NUMBER	PERCENT OF LIFE	TORQUE (lb-in)	THRUST (lb)
Standard	25	14	41-46	355-415
Standard	100	57	40-51	345-476
Standard	150	86	46-54	355-485
Standard	174	99	46-59	350-475
Modified	75	14	40-50	345-355
Modified	300	58	41-45	340-350
Modified	450	87	40-45	345-355
Modified	514	99	41-58	345-355

*"Standard" is the chisel-point drill with 30.5-degree helix angle; "Modified" is the special drill with 20-degree constant helix angle.

1. TRAINOR, R.

2. COOLANT-FED DRILLS - PRODUCTION PLUS

3. THE TOOL AND MANUFACTURING ENGINEER, June, 1969, pp. 22-25

4. When drilling nickel and titanium alloys, a straight cutting oil provides good lubrication but does not dissipate heat. A 1:10 solution of heavy duty water soluble oil will produce a 400 to 900 percent increase in drill life over straight cutting oil.

   Oil hole drills when used with high pressure coolant delivery present increases in tool life and penetration rates. When drilling titanium and nickel alloys 800 to 2400 percent increases in tool life and 250 to 500 percent increases in penetration rates over conventional drills can be expected.

   A comparison of standard and oil hole drills is given in Tables 1 and 2.

Table 1. Comparative Performance of Conventional and Coolant-Hole Drills in Titanium Alloy

Drill Size & Material		Drill Style	Speed (rpm & sfm)	Feed (ipr)	Inches per Minute (ipm)	Increase in Speeds & Feeds (Percent)	No. Pull-Outs for Chips & Heat	Time Per Hole (min)	Holes per Drill & Condition of Drill	Increase in tool life (percent)	Linear Material Removed (inch)
9/16	T-15	Twist	127 (19)	.002	.254	—	9	16.7*	1 Poor	—	3.5
	HSS	Coolant hole	165 (24)	.0055	.908	257	0	3.9	9 Good	800	31.5
19/32	T-15	Twist	127 (2)	.002	.254	—	9	16.7*	1 Poor	—	3.5
	HSS	Coolant hole	165 (26)	.009	1.485	485	0	2.4	9 Good	800	31.5
⅝	T-15	Twist	127 (21)	.002	.254	—	9	16.7*	1 Poor	—	3.5
	HSS	Coolant hole	165 (27)	.009	1.485	485	0	2.4	9 Good	800	31.5
31/32	T-15	Twist	98 (25)	.002	.196	—	9	20.6*	1 Poor	—	3.5
	HSS	Coolant hole	127 (31)	.009	1.143	485	0	3.0	9 Good	800	31.5
1-1/16	T-15	Twist	98 (27)	.002	.196	—	9	20.6*	1 Poor	—	3.5
	HSS	Coolant hole	127 (36)	.0055	.700	257	0	5.0	9 Good	800	31.5
1-11/32	T-15	Twist	45 (18)	.002	.090	—	9	38.7*	1 Poor	—	3.5
	HSS	Coolant hole	98 (35)	.0055	.540	500	0	6.2	9 Good	800	31.5

*Includes 20 seconds per [illegible]

Table 2. Comparative Performance of Conventional and Coolant-Hole Drills In Incoloy 901

Drill Size & Material		Drill Style	Speed (rpm & sfm)	Feed (ipr)	Inches per Minute (ipm)	Increase in Speeds & Feeds (Percent)	No. Pull-Outs for Chips & Heat	Time Per Hole (min)	Holes per Drill & Condition of Drill	Increase in tool life (percent)	Linear Material Removed (inch)
31/64	T-15	Twist	170 (22)	.0044	.75	—	4	3.26*	3 Poor	—	4.2
	HSS	Coolant hole	190 (25)	.0060	1.14	53	0	1.23	11 Good	267	15.5

*Includes 20 seconds per [illegible]

1. NAURECKAS, E. M. and GABRICK, J.

2. PHOTOELASTIC TECHNIQUES TO EVALUATE CUTTING FORCES DURING DRILLING

3. ASTME PAPER NO. MR69-172, 1969

4. The stress distribution on the cutting edge of a drill was analyzed using photoelastic techniques.

   The stress distribution due to the thrust force was determined by drilling a hole to a depth of one diameter and aligning the cutting edge of the drill with the center of the plastic specimen. A thrust force was applied and the resulting stress distribution photographed.

   This process was repeated with drills of different shapes until an optimum design was reached.

1. RICH, E. A.

2. THE GROWING ACCEPTANCE OF COOLANT FED DRILLING AND CUTTING TOOL SYSTEMS FOR DRASTIC COST REDUCTION IN METALWORKING

3. ASTME TECHNICAL PAPER NO. MR69-173, 1969, pp. 1-16

4. The advantages of coolant fed drills by the increased penetration rates possible. When compared to regular twist drills, penetration rates could be increased 370% in soft steels, 250% in P-1 steels and 150% in cast meehanite. When drilling stainless steels, the penetration rates were increased 170-220% with a 4000-6000% increase in tool life using the pulsating pressure system.

   By introducing the coolant through a coolant fed drill, the heat is dissipated more rapidly and the hardness of the drill is not reduced. With the chips being forced out the flutes "woodpeckering" is eliminated.

   A comparison of penetration rates for standard drills and coolant fed drills for various materials is shown in Fig. 1. The recommended speeds, feeds and point geometries for different metals is given in Fig. 2.

DRILLING RATE FACTS

Comparative Penetration Rates Being Experienced With the Jet Pulser Pump
With Oil Hole Drills VS. Regular Drills With Flood Coolant in Various Mfg. Plants

(Drilling Penetration Rate Feed per Revolution of Drill
Multiplied by R.P.M. of Drill Expressed in Inches Per Minute)

Material	Flood Coolant Regular Drills Former Standard	Pulsating Pressure With Oil Hole Drills New Standard	% Increase
Steels			
1018	2 86"	9.83"	243%
1020	1.66"	8.125"	390%
1035	4.73"	11.76"	150%
1045	1.69"	5 88"	248%
1050	3.00"	6 00"	100%
1212	8.2"	16.6"	100%
3140	3.03"	4.5"	49%
4140	1.73"	9.90"	470%
4150	.88"	3.79"	330%
4340	1.8"	6 72"	273%
5140	95"	3.45"	263%
6175	1 73"	6.20"	259%
8620	4.75"	16.4"	245%
Aluminum			
Aluminum (4117)	14.31"	30.8"	115%
Aluminum	2.25"	8.85"	293%
Aluminum	2.8"	10.5"	275%

Material	Flood Coolant Regular Drills Former Standard	Pulsating Pressure With Oil Hole Drills New Standard	% Increase
Stainless Steels			
14-7	2.7"	5.5"	102%
17-4	.88"	3.08"	250%
304	1.13"	2.84"	152%
309	2.5"	9.6"	284%
316	1.33"	5.7"	328%
421	1.06"	4.21"	296%
Cast Steel			
300 BN	2.64"	10.92"	313%
30 Carbon	1.87"	9.24"	395%
4140 A	1.5"	4.15"	177%
1010	2.5"	6.64"	166%
52% Mach.	2.16"	8.5"	293%
Cast Iron			
#30	6.0"	13.2"	120%
275 BN	8.1"	14.87"	84%
Ductile Iron	6.00"	10.5"	74%

Special Metals Material	Flood Coolant Regular Drills Former Standard	Pulsating * Pressure With Oil Hole Drills New Standard	% Increase
Incoloy 800	.31"	3.20"	930%
Inconel 600	.39"	1.56"	300%
Inconel 718	.192"	1.925"	900%
Inconel X750	.108"	1.54"	1300%
Titanium AMS4926	.57"	1.43"	156%
Waspaloy (13% Mach.)	.52"	.67"	29%
4340 Modified - 54 R.C.	.175"	1.05"	500%
Dead Soft Copper	Undrillable	19.8"	——
Aluminum Bronze	1.78"	10.8"	503%
D6AC Mold Stl. - 47 R.C.	.70"	2.53"	262%
P20 Mold Steel	1.09"	7.2"	560%

*Note - No woodpeckering required.

Jet Pulser Pumping Liquid Coolant VS. Mist through Coolant Fed (Oil Hole) Drills
(Penetration Rates-In./Min.)

Material	Mist	Liquid Pulsating Pressure	% Increase
1018-1020	7.04"	13.6"	92%
1030-200 BN	7.6"	12.48"	64%
1035	4.73"	11.76"	148%
1212	8.2"	16.6"	102%
SAE 515	5.08"	11.99"	136%

Note -- Above rates are <u>medians</u> - not maximum.
<u>No allowance</u> is made for elimination of woodpeckering.

E A Rich/ef 1/8/68

FIG. 1.

BALCRANK JET PULSER PUMP USED WITH COOLANT FED (OIL HOLE) DRILLS

MASTER GUIDE TO FEEDS, SPEEDS, AND SUGGESTED DRILL POINT GEOMETRY

(For High Speed Steel coolant fed drills using liquid coolant.
Reduce feeds and speeds 40% for mist applications.)

MASTER GUIDE FOR METALS

Material	Speed	Feed	Point Geometry
Non-Ferrous	A	1	t
Brass, Aluminum and Magnesium			
Copper Base and Non-Ferrous Alloy	B	2	u
Carbon Steel			
1010 thru 1040 110-185 BHN	C	2	u
1040 thru 1095			
170-250 BHN	E	3	u
260-320 BHN	E	3	v
330-400 BHN	F	4	v
Alloy Steels			
2340 thru 8740			
150-240 BHN	D	3	u
240-320 BHN	E	4	v
320-400 BHN	F	5	w
400-460 BHN	F	6	y
460-500 BHN	G	6	y
Cast Iron			
100-240 BHN	C	3	v
240-500 BHN	D	3	w
Cast Steel			
Up to 200 BHN	E-D	3	u
200 to 300 BHN	E-D	4	u
300 to 400 BHN	F	4	v
400 to 450 BHN	G	5	w
Exotic Materials			
High Nickel Alloys	G-F	6	x
Titanium Alloy	G-F	4-5	v-z

FEED TABLE

Feed #	Drill Size				
	1/4"-1/2"	1/2"-3/4"	3/4"-1"	1"-1-1/2"	1-1/2"-2"
1	.008" to .015	.012" to .020	.018" to .030	.030" to .040	.035" to .045
2	.007 .012	.012 .018	.018 .022	.022 .027	.025 .030
3	.005 .010	.010 .015	.013 .018	.018 .022	.022 .030
4	.004 .007	.007 .010	.010 :013	.013 .018	.018 .022
5	.003 .006	.006 .009	.009 .0105	.0105 .0135	.0135 .018
6	.001 .004	.003 .006	.005 .008	.007 .010	.008 .012

SPEED TABLE

A - 200 SFM and above
B - 150 to 200 SFM
C - 100 to 150 SFM
D - 80 to 120 SFM
E - 60 to 100 SFM
F - 40 to 80 SFM
G - 10 to 40 SFM

Feed X Speed = Rate of Penetration

POINT GEOMETRY CODE

Class #	
t	$85^\circ - 100^\circ$ included angle
u	$100^\circ - 120^\circ$ included angle
v	$120^\circ - 140^\circ$ included angle
w	$135^\circ - 140^\circ + 90^\circ$ secondary included angle
x	$135^\circ - 140^\circ + 90^\circ$ secondary included angle with a 5°-10° positive notch to leave web approximately 8%-10% of drill diameter.
y	$135^\circ - 140^\circ + 90^\circ$ secondary included angle with a 5°-10° negative notch to leave web approximately 8%-10% of drill diameter.
z	$135^\circ - 140^\circ + 90^\circ$ secondary included angle with a 5°-10° negative notch to leave web approximately 8%-10% of drill diameter with grind .001" to .003" off center line of drill. (Some users have found this off-center grind helpful on some exotic materials such as Titanium and Titanium Alloys. This is used on holes of 3 or more diameters in depth.)

R.G./ef 3/29/68

FIG. 2.

1. HEMKEN, P. C. and HARDY, J. M.

2. THE FIRST STEP IN ACCURATE TOOL LIFE PREDICTIONS FOR DRILLING

3. ASTME PAPER NO. MR69-417, 1969

4. Optimum tool life is considered from the point of view of acquisition and reconditioning of drills.

   Tests were run on drills from different manufacturers in the condition that they were received and there was a substantial difference in drill life for different manufacturers. After regrinding the drills on the same machine tests were run again which indicate that although drill life did increase the order of rank of the various drill manufacturers did not change.

   By instituting a step by step regrinding procedure the drill life could be increased 15-72% and good drill grinding equipment could increase the drill life an additional 41-55%.

   When testing drills ground on different machines it was found that there was a difference in drill life among the drills produced by the various grinders.

   It was found that over 40% of the drills that had been determined as scrap could be salvaged and used again if proper training were given in determining scrap drills.

1. NAURECKAS, E. M.

2. DEVELOPMENT AND TESTING OF THE RADIAL LIP DRILL

3. ASTME, PAPER NO. MR69-420, 1969

4. A test was run on speed and thrust in cutting 1-in thick C-1018 steel plate with no coolant. A 7/16 in. diameter drill was used with a speed of 115 SFM and a feed of about 0.006 ipr. The results show about the same thrust values for both the conventional drill and the radial point drill for the first 10 holes. The thrust for the conventional drill increased from 400 lbs. to over 600 lbs. while the thrust on the radial lip drill remained constant at about 400 lbs. The conventional drill failed after 27 holes while the radial lip drill showed little wear after 150 holes. The radial lip drill showed less torque throughout the test.

   Due to the longer cutting edge, the forces on the drill are lower at a given feed rate. At the point of drill breakthrough the radial lip drill has enough material to support the drill and prevents the drill from extruding the remaining material. This allows the drill to cut the remaining material and the hole is burr-free.

   On size holes are produced when the lip height of both cutting edges are the same. Chip thickness varies from the chisel edge out to the margin. The chip has a tendency to curl and causes the chips to break into short pieces.

1. KOZHEVNIKOV, D. V., et al

2. DRILLING WITH CEMENTED-CARBIDE-TIPPED DRILLS

3. MACHINES & TOOLING, 1969, Vol. 40, No. 12, pp. 26-28

4. Comparison tests were run on carbide tipped drills, with and without oil holes, and high speed steel drills with and without oil holes. The materials drilled were plain carbon steel 45, high manganese austenitic steel 45G17YU3 and a cast creep-resisting steel KH24N12SL.

The carbide drills, Fig. 1, were tipped with VK8 cemented carbide and the high speed steel drills were R9 and R6M3.

Table 1 indicates that the carbide tipped drills operating with a pressurized coolant delivery system permit higher penetration rates than the HSS drills using flood or pressurized coolant. The carbide tipped drills with oil holes fractured near the chisel edge on the first hole.

The wear on the clearance face, for the oil hole carbide drills, versus drilling time for 45G17YU3, KH24N12SL and 45 steel respectively, is shown in Fig. 2.

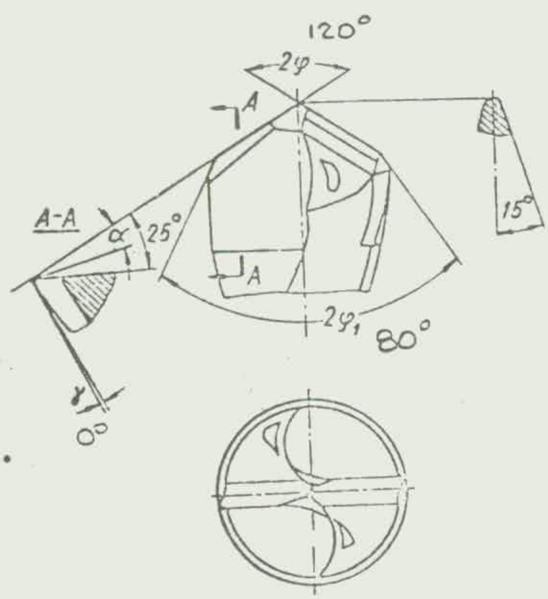


FIG. 1. Drill geometry

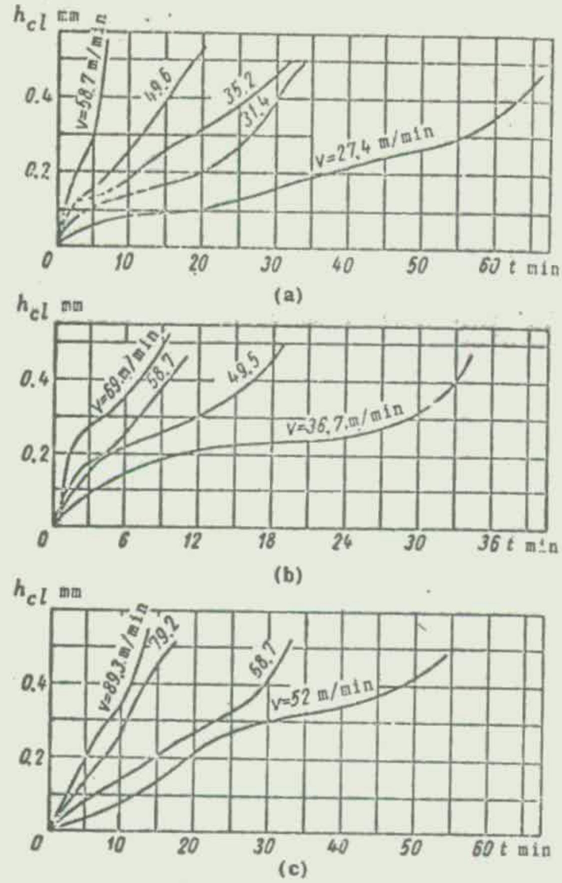


FIG. 2. Wear vs. Drilling Time

Grade of steel machined	Drill, cutting-fluid pressure p	Drilling rate mm/min with drill life min			
		10	20	40	60
45G17YU3	High-speed steel R9, $p = 0$	16.4	13.9	11.2	9.6
	Ditto, $p = 6 kgf/cm^2$	30	26.3	23.4	21.5
	Ditto, $p = 25 kgf/cm^2$	37.8	31.2	26.2	23.4
	Sestroretsk, $p = 25 kgf/cm^2$	62.3	56	38.5	31.2
KH24N12SL	High-speed steel R9, $p = 0$	30.5	27.7	24.8	23.1
	Ditto, $p = 6 kgf/cm^2$	34.3	31	27.6	27
	Ditto, $p = 25 kgf/cm^2$	35.8	31.9	28	27.2
	Sestroretsk, $p = 25 kgf/cm^2$	108	74.7	52.5	41.5
45	High-speed steel R9, $p = 0$	238	227	209	205
	Ditto, $p = 6 kgf/cm^2$	333	293	264	243
	Ditto, $p = 25 kgf/cm^2$	362	314	276	254
	Sestroretsk, $p = 25 kgf/cm^2$	475	357	276	234
	High-speed steel R6M3, $p = 0$	272	257	234	230

Table 1.

1. KISELEV, N. F.

2. TESTING NGL-205 AND SDMU EMULSIONS FOR DRILLING OF STEEL

3. MACHINES & TOOLING, 1969, Vol. 40, No. 11, pp. 55

4. Drill life tests were conducted on alloy steels (BHN 286-320) with 12.7 mm diameter HSS (R18) drills. A cutting speed of 10 m/min and a feed rate of .19 mm/rev were used with a depth of three diameters. The cutting fluids were delivered at a rate of 8-10 litres/min.

   It was found that the optimum concentration for the NGL-205 and SDMU emulsions was 5 percent while for the E emulsions was 7 percent. The NGL-205 and SDMU emulsions increased drill life by about 30 percent over the E emulsion as shown in Fig. 1.

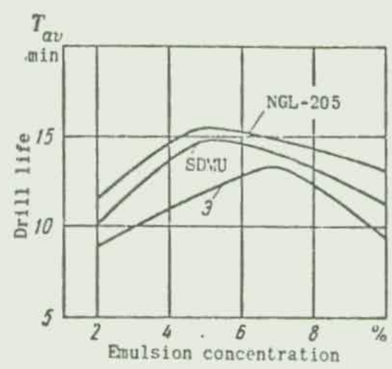


FIG. 1. Effect of concentrations of various emulsions on drill life

1. VICTOR, H.

2. SCHNITTKRAFTBERECHNUNGEN FÜR DAS ABSPANEN VON METALLEN
(Calculation of cutting forces by metal removal processes)

3. WERKSTATTSTECHNIK, 1969, Vol. 59, No. 7, pp. 317-327

4. From the figures below, the torque in drilling can be computed from the net-cutting force for each cutting by twist drills as follows:

$$Md = F_s \cdot 0.34 \cdot \frac{D}{10^3} \text{ (mkp)}$$, Drilling in a solid workpiece

$$Md = F_s \cdot 0.54 \cdot \frac{D}{10^3} \text{ (mkp)}$$, Predrilled to a diameter equal to the length of the chisel edge

where

D = Dia. of drill (mm)

$S_z = S_{ges}/2$ = Feed rate for each cut (mm/Rev. per lip)

= Point angle

F_s = Specific force

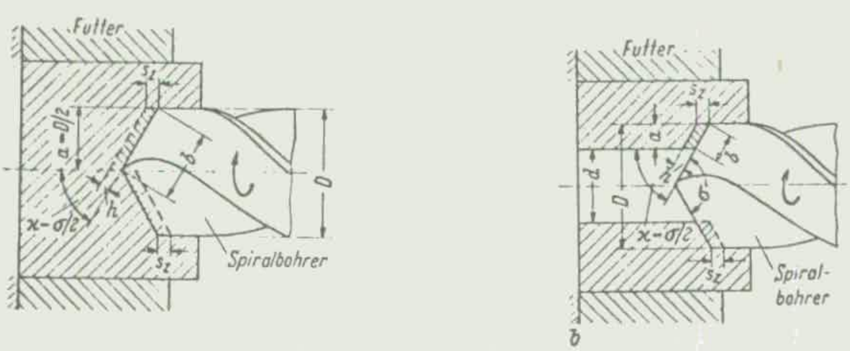


FIG. 1. Drilling in solid and predrilled workpiece

1. BHATTACHARYYA, A. and HAM, I.

2. DESIGN OF CUTTING TOOLS - USE OF METAL CUTTING THEORY

3. PUBLISHED BY SOCIETY OF MANUFACTURING ENGINEERS, DEARBORN, MICH., 1969

4. The design of clearance angles along the cutting edge of drills depends not only upon the helix angle (θ) or radial location, but also upon the method of lip grinding. The relief angle should be such that the actual clearance angle is never zero.

Consider any lip, AB, shown in Fig. 1, lying along the surface of a cone whose axis is O_1O_1, and is inclined by 45 deg. to the drill axis. The cone angle is 2σ, while the point angle is 2ρ. The plan view shows that the cone axis, O1O1, is offset from the drill's transverse axis OO by an amount K. Any point on the cutting edge is at a distance $d_o/2$ from axis OO, and also at a distance C_o from axis O_1O_1 in plan view, when:

$$K = C_o + \frac{d}{2}$$

Fig. 2 shows that two cone surfaces meet at the lip at an inclination to each other. Hence a point R located on the cutting edge lies at a distance $1 + d_i/2$ on the grind cone while, in the plan view, its location is between the projection of OO and O_1O_1.

A section through the $\gamma - \gamma$ axis at R on the grinding cone shows an ellipse of major axis 2a and minor axis 2b. The equation of the ellipse is given by:

$$\frac{x^2}{a^2} + \frac{y^2}{b^2} = 1 \qquad (1)$$

From the geometry of Fig.

$$\tan\beta = \frac{dy}{dx} \qquad (2)$$

From Eq. (1)

$$y^2 = \left(1 - \frac{x^2}{a^2}\right) b^2$$

Differentiating:

$$y\,\frac{dy}{dx} = \frac{b^2}{a^2}\,x \cdot dx$$

Therefore:

$$\frac{dx}{dy} = \frac{b^2}{a^2} \cdot \frac{x}{y} \tag{3}$$

Again, from Eq. (1):

$$x = a\sqrt{1 - \frac{y^2}{b^2}}, \qquad y = C_o \tag{4}$$

From which:

$$x = a\sqrt{1 - \frac{C_o^2}{b^2}} \tag{5}$$

Substituting Eq. 4 and Eq. 5 into Eq. 3:

$$\tan\beta = \frac{dy}{dx} = \frac{b^2 a\sqrt{1 - \frac{C_o^2}{b^2}}}{a^2 C_o} = \pm \frac{b}{a}\sqrt{\frac{b^2 - C_o^2}{C_o}}$$

Therefore:

$$\tan\alpha = \frac{1}{\tan\beta} = \frac{a}{b}\,\frac{C_o}{\sqrt{b^2 - C_o^2}} \tag{6}$$

Where: $C_O = K - \frac{d_O}{2}$

From the geometry of Fig. 2:

$$a = \left[\frac{\ell + \frac{d_i}{2}}{2\sin\rho}\right]\tan\sigma \tag{7}$$

$$b = a\sqrt{1 - \tan^2\sigma} \tag{8}$$

Substituting Eq. 7 and Eq. 8 into Eq. 6:

$$\tan\alpha = \frac{C_o}{\sqrt{1-\tan\alpha}\,\sqrt{\left(\frac{\ell+\frac{d_i}{2}}{2\sin\rho}\right)\tan 2\sigma\left(1-\tan^2\sigma\right)-C_o^2}} \tag{9}$$

Where: 2σ = Grind cone angle
2ρ = Point angle of the drill

$$C_o = K - \frac{d_o}{2}$$

The clearance angle, α, at any location $r_i = d_i/2$ varies. The grind cone must be designed so that:

$$4 \text{ to } 6 \geq \alpha_{min} > 0$$

Usually:

ℓ = 1.8D to 1.9D
ρ = 20 deg to 45 deg
σ = 13 deg to 15 deg
K = .07D to .05D
D = Nominal diameter of the drill

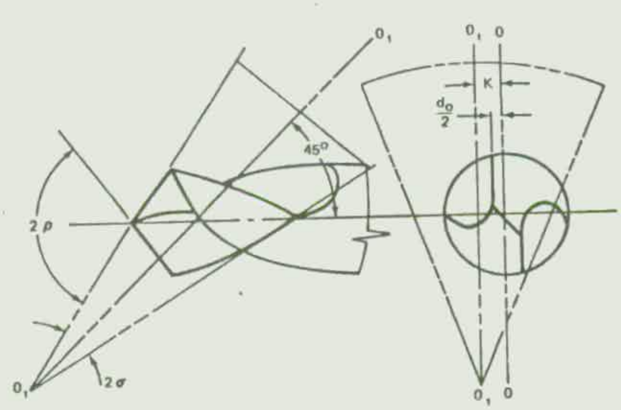


FIG. 1. Orientation of grind cone with respect to the drill point

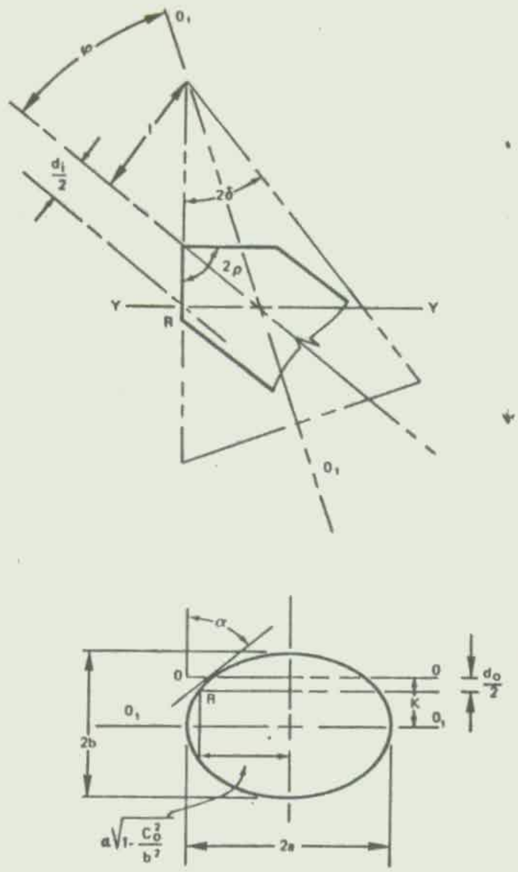


FIG. 2. Geometry of clearance surface with respect to the grind cone

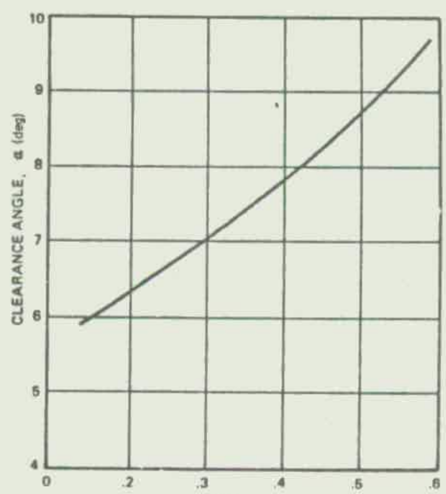


FIG. 3. Variation of the clearance angle across the lip of a typical twist drill

1. SPUR, G.

2. SCHNITTKRAFTMESSUNG BEIM BOHREN MIT SPIRALBOHRERN (Drilling Force Measurement of Twist Drills)

3. KURZBERICHTE DER HOCHSCHULGRUPPE FERTIGUNGSTECHNIK DER TECHNISCHEN HOCHSCHULEN UND UNIVERSITÄTEN DER BUNDESREPUBLIK DEUTSCHLAND, 1969

4. Applying the analysis of Kienzle and Victor, the drilling forces can be established by the following formulae:

$$\text{Torque: } Ps = \frac{D}{2 \cdot \sin \varkappa} \cdot \left(\frac{s}{2} \cdot \sin \varkappa \right)^{1-m} \cdot ksl.1$$

$$\text{Thrust: } P_{\nu} = D. \left(\frac{s}{2} \cdot \sin \varkappa \right)^{1-y} . k_{\nu} nl.1$$

The effect of drilling speed on drilling force is given in Fig. 1. The source of radial force can be classified as:

1) Unsymmetrically ground point
2) Unsymmetrical flute
3) Non-uniformity of sharpness on both lips
4) Runout of drill
5) Inhomogeneity of work material
6) Clamping by imperfect chip flow
7) Non-uniformly supplied coolant

The effect of hole depth was introduced in Fig. 2.

The tendency of a drilled hole to be oversize is related to the radial forces. Fig. 3 indicates the relationship between radial force and hole oversize. The effect of length of drill on the drill life was investigated as shown in Fig. 4.

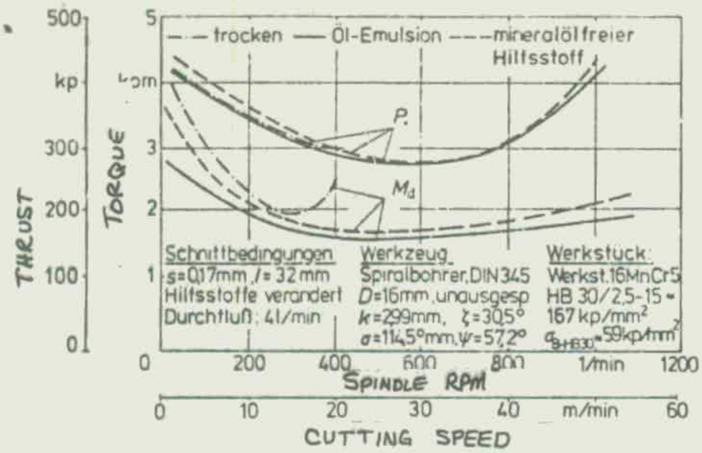


FIG. 1. Effect of cutting speed on torque and thrust

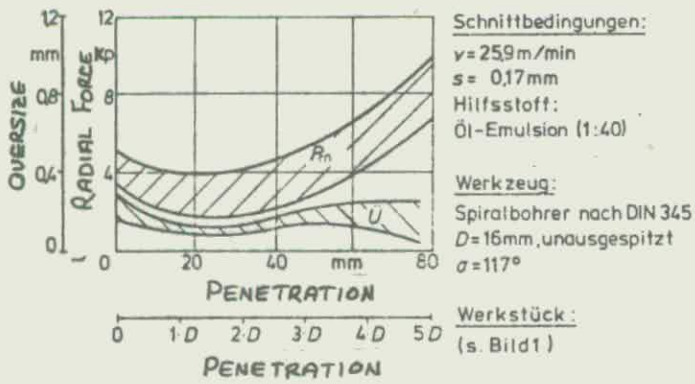


FIG. 2. Effect of hole depth on oversize

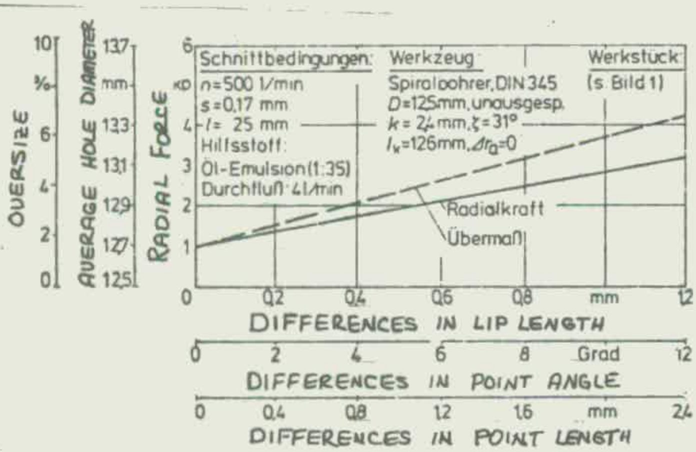


FIG. 3. Relationship between radial force and oversize

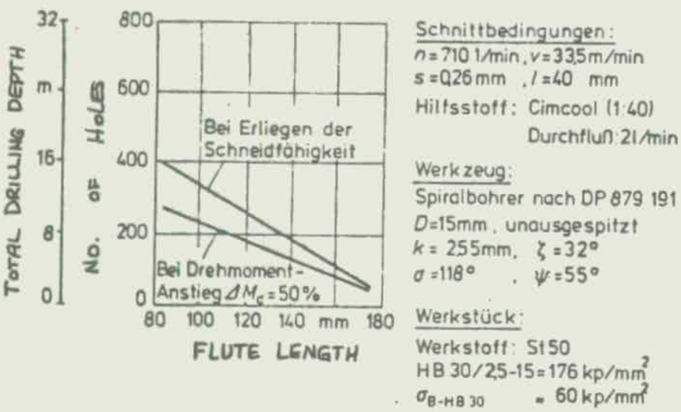


FIG. 4. Effect of length of drill on drill life

1. KONOPLEV, V. N. and URLAPOV, G. P.

2. INCREASING THE LIFE OF TWIST DRILLS AND TAPS

3. RUSSIAN ENGINEERING JOURNAL, Vol. 49, No. 4, 1969, pp. 77-79

4. This experiment considered the possibility of increasing the life of high-speed steel twist drills in machining titanium alloys and stainless steels by breaking the resulting t.e.m.f. circuit and introducing a compensating e.m.f. to the cutting zone.*

The cutting tools used in the tests were standard type 8.5 mm diameter twist drills in R18 high-speed steel. To ensure the maximum accuracy and minimum eccentricity of the test drill cutting edges, the drills were ground flat on the clearance faces, then lapped on an iron disc in a special fixture to remove grinding burns and to produce a lip clearance angle α of 12° and a point angle 2ϕ of 125°. The radial eccentricity of the drill at the end of the working section did not exceed 0.02 mm. When the drills were reground, not more than 1.5 to 2 mm of metal was removed, so that the length and consequently the stiffness of the drill were maintained practically constant in each series of tests.

To ensure that the t.e.m.f. did not affect the test results, all the drills were sorted after grinding and lapping according to t.e.m.f. values. Deep holes (20 mm deep) were then drilled in titanium alloy specimens. The variation in the hardness of the specimens did not exceed 10 Brinell units. The tests were carried out in a vertical drilling machine, the range of speeds being 97 to 1360 rev/min and the range of feeds 0.1 to 0.81 mm/rev. The cutting fluid used was a 10% soluble oil emulsion.

The positive thermal currents at various cutting speeds were first determined (Fig. 1). A diagram of the test arrangement is shown in Fig. 2. The twist drill was insulated from the spindle by a Textolite (resin-dipped fabric laminate) bush. The specimen blank was also insulated from the machine table by Textolite pads. The reliability of the insulation was periodically checked by an ohmmeter. The electrical circuit of the test arrangement allowed various currents (of positive and negative sign) to be introduced to the cutting zone. A constant sliding contact resistance was obtained and the effect of parasitic e.m.f.s. was excluded by using a slip-ring having a spring-mounted graphite brush. The leads were screened. The wear criterion used in determining the intensity of drill wear was a 1 mm wear flat on the clearance face. A constant current of opposite sign to the thermal current was

4. (Continued)

passed through the cutting zone; its magnitude was determined from the graph given in Fig. 1. The wear on the drill clearance face was measured by a toolmaker's microscope. The relationship between drill wear and number of drilled holes is given in Fig. 3.

To determine the effect of the compensating e.m.f. on drill life, a counter-current of a magnitude depending on the cutting force was passed through the cutting zone (Fig. 1). It will be seen from the graph in Fig. 4 that with such a compensation drilling method, drill life is three times greater than in conventional drilling. The life of a drill held in a Textolite bush and connected to the machine spindle by a special conductive yoke was slightly higher than in conventional drilling, but still less than that with the broken t.e.m.f. circuit.

In a subsequent series of tests the drill-workpiece-machine electrical circuit was broken by insulating the drill from the spindle and the workpiece from the machine table. Results of the life tests are given in Fig. 5, from which it will be seen that with a broken circuit drill life is higher than in conventional drilling, but the increase is less than in the previous tests.

* Thermo-electromotive force

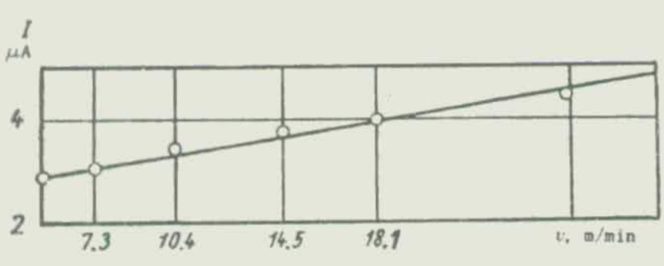


Fig. 1. *Thermal current plotted against cutting speed.*

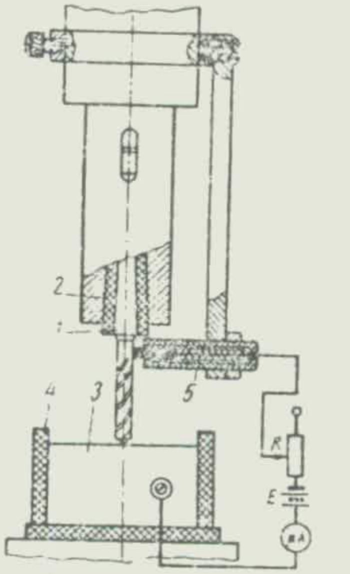


Fig. 2. *Diagram of test arrangement: 1 - drill; 2 - Textolite bush; 3 - blank; 4 - Textolite pads; 5 - graphite brush.*

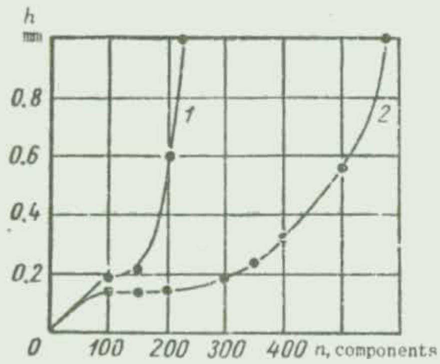


Fig. 3. *Wear h on clearance face of 8.5mm diameter drill plotted against number n of holes drilled at v = 7.3m/min in: 1 - conventional drilling; 2 - compensation drilling.*

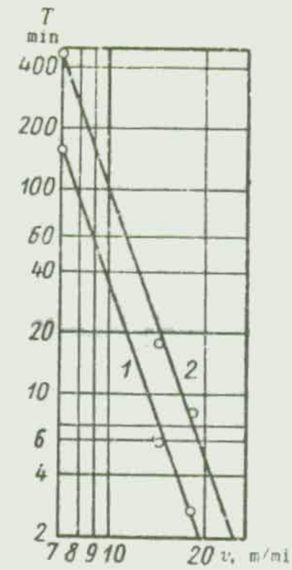


Fig. 4. *Drill life plotted against cutting speed in: 1 - conventional drilling; 2 - compensation drilling.*

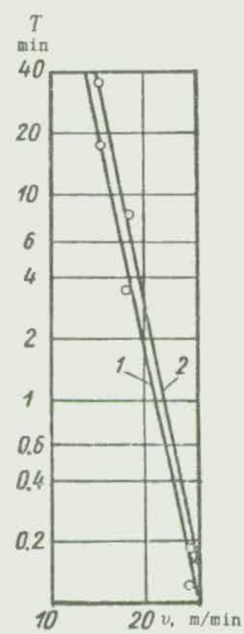


Fig. 5. *Drill life plotted against cutting speed in: 1 - conventional drilling; 2 - drilling with the machine-workpiece-tool circuit broken.*

1. KOZHEVNIKOV, D. V. and SHCHEPETIL'NIKOV, Yu. V.

2. INCREASING THE LIFE OF HIGH-SPEED STEEL TWIST DRILLS

3. RUSSIAN ENGINEERING JOURNAL, Vol. 49, No. 5, 1969, pp. 77-78

4. Tests to determine the effect of coolant pressure on drill life and also in drilling the tough high-alloy steels, were carried out by 19 mm diameter drills made in R9 high-speed steel by the sector rolling method. The coolant (7% soluble oil in water) was fed to the cutting zone at a pressure of 45 kgf/cm^2 through a rotary seal, the machine spindle, and a hole through the drill core. Blind holes of a depth equal to 2.5 times the diameter were drilled in 1KH18N9T Cr-Ni steel, 45G17YU3 Mn steel and carbon steel 45.

   When drilling the 1KH18N9T steel an increase in coolant pressure in the supply system from 0.2 to 45 kgf/cm^2 increased drill life four-fold (Fig. 1). The coolant flow in the system at this higher pressure was increased by 12 to 15 times, which greatly improved the heat extraction rate from the cutting zone.

   The relationships between drill life T and cutting speed v are given in Fig. 2. An increase in coolant pressure to 25 kgf/cm^2 when drilling the 1KH18N9T steel increased drill life by about 20 times at a constant cutting speed. The harder the steel is to drill, the greater the increase in drill life. The increase in output for a drill life of 20 minutes with an increased coolant pressure of 25 kgf/cm^2 was 50% for the 1KH18N9T steel, 125% for the 45G17YU3 steel, and with a coolant pressure of 12 kgf/cm^2 it was 25% for the steel 45.

   The considerable increase in drill life can be explained by the smaller degree of wear in conjunction with the reduced heating of the contact surface, see Fig. 3.

   The tests showed that the high-pressure internal cooling of twist drills in drilling steels considerably increased the output and improved drill life. The introduction of this method in production operations does not involve any special technical difficulties. Its economy has also been confirmed.

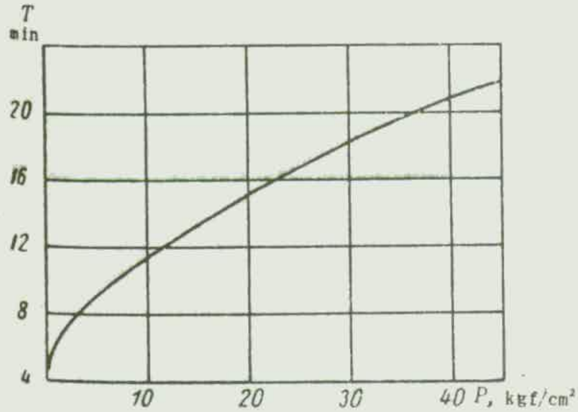


Fig. 1. *Effect of coolant pressure* p *on life* T *of high-speed steel twist drills with internal cooling when machining 1KH18N9T steel: (*v *= 23.8m/min;* s *= 0.22mm/rev).*

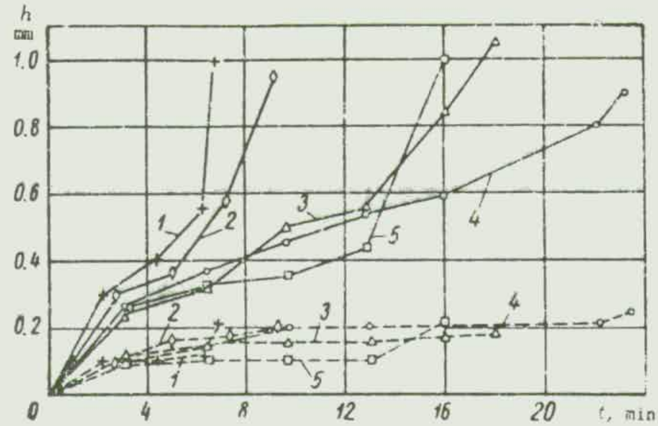


Fig. 3. *Relationship of wear* h *on clearance face (continuous lines) and at centre of main cutting edges (broken lines) to time of operation of high-speed steel drills with internal cooling and to coolant pressure* p *when machining 1KH18N9T (*s *= 0.22mm/rev;* v *= 23.8m/min):*
1 - internal cooling from machine pump;
2 - p *= 5kgf/cm²; 3 -* p *= 25kgf/cm²;*
4 - p *= 45kgf/cm²; 5 -* p *= 15kgf/cm².*

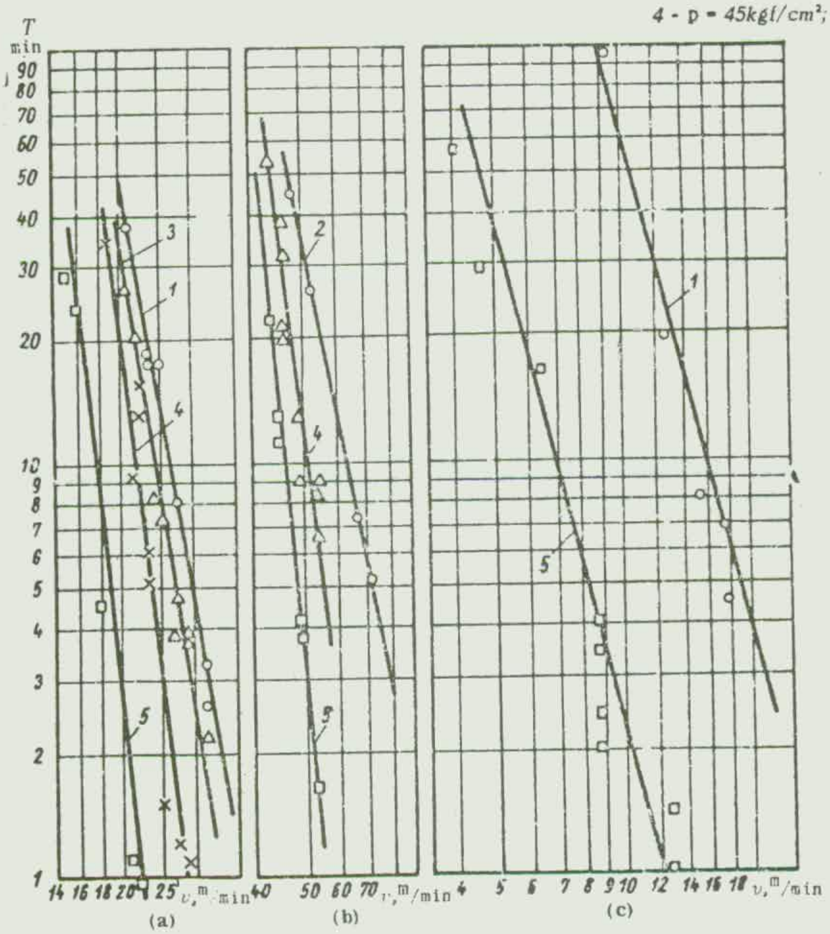


Fig. 2. *Effect of cutting speed* v *and coolant pressure* p *on twist drill life* T *when machining various steels (*s *= 0.22mm/rev): (a) - 1KH18N9T steel; (b) - steel 45; (c) - 45G17YU3 steel;*
1 - p *= 25kgf/cm², 2 -* p *= 12kgf/cm²;*
3 - p *= 5kgf/cm²; 4 - internal cooling from machine pump; 5 - flood cooling.*

1. RESNIKOV, A. N. and BOITSOVA, L.V.

2. DIAMOND DRILLING OF GLASS

3. RUSSIAN ENGINEERING JOURNAL, Vol. 49, No. 9, 1969, pp. 59-61

4. The results are given of an investigation into the cutting process and temperature generated when diamond drilling glass, and the operating capacity of drills of natural and synthetic diamonds. Formulae are given for determining drilling torques, penetration speed, output, and the specific consumption of diamond. Recommendations are made for drilling systems for diamond drills of 12 to 25 mm dia, and for the selection and modernization of equipment.

Drilling experiments were performed on blanks of industrial glass using special annular-shape diamond drills made by a powder metallurgy technique with natural diamonds of the following grain size: A16, A25, A32 with an M1 bond, diamond concentration in bond 100%. Tests were also carried out using drills made by a plating process with synthetic diamonds of grain size: ASV16, ASV25, ASV32 with a nickel bond and concentrations of 100 to 150%. The drills used had an external diameter D = 12 to 25 mm and an internal diameter d = 9.6 to 22.6 mm with a diamond-bearing annulus of thickness h = 3 mm and a tubular body with taper shank. The length of the drill body with natural diamonds was 33 mm and with synthetic diamonds 35 mm, and the total lengths of the drills were respectively 80 and 76 mm. More than 3,000 holes were drilled with an axial load P = 10 to 40 kgf, which corresponded to a specific load P_{sp} = 11 to 70 kgf/cm^2, peripheral speed v = 0.9-5.8 m/s and a penetration speed s = 0.55-2.3 mm/s with cooling by an emulsion of 60 parts water and 0.5 parts of triethanolamine.

It is seen from the graph of Fig. 1 that temperature θ increases with increase in the axial force and the peripheral speed of the drill. The mean temperature generated when diamond drilling glass under the systems investigated did not exceed 200°C, and the calculated temperature on the grain did not exceed 700°C.

A resistance transducer was used to record the penetration speed s and its change during operation; the results of measurement were recorded on a loop oscillograph. Typical oscillograms are shown in Fig. 2. The record of the output signal from the resistance transducer (sloping line) is not a straight line; this shows the unevenness of the penetration speed when drilling the hole.

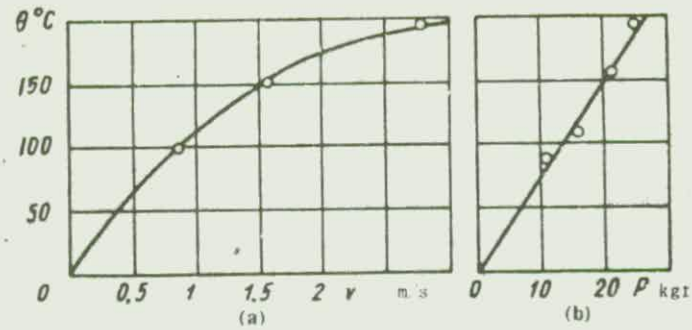


Fig. 1. Relationship of mean temperature θ of operating end of diamond drill to: a - drill peripheral speed v (with P = 25kgf); b - axial force P on drill (when v = 2.8m/s). (Drill 12mm dia with natural diamonds of grain size A16 with M1 bond, 100% concentration; component material industrial glass).

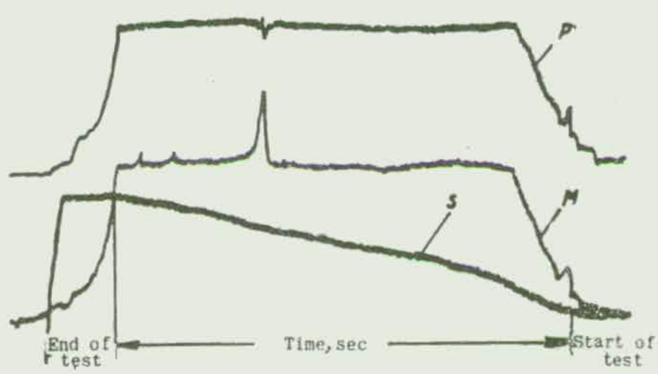


Fig. 2. General type of oscillogram recording axial force P, torque M and penetration speed s.

1. FEDYAEVA, V. M. AND GARINA, T. I.

2. RATIONAL USE OF SMALL DRILLS

3. MACHINES AND TOOLING, Vol. 40, No. 12, 1969, pp. 31-32

4. The tests involved drilling steel 45 components, using a bench-mounted drilling machine having a mechanical feed in the range 0.003-0.1mm/rev, and a speed in the range 2050-18 510 rev/min. Twist drills of 0.5, 0.7 and 1mm diameter were used; these were first tested by drilling with constant pressure. The tests were conducted without a jig, the drilling depth being four diameters (with cutting fluid).

During the tests the wear of the drill elements was systematically observed without the drill having to be removed from the machine. It was found that drills up to 1mm diameter wear simultaneously on the clearance faces along the principal cutting edges, at the corners, and on the chisel edge, the latter zone giving rise to the most intensive wear (Fig. 1). The chisel edge is gradually rounded-off; fracture of the drill is preceded by formation of a taper, which fractures; a flat is then formed at that point on the chisel edge. Up to the moment when the wear on the chisel-edge starts to increase rapidly, the wear on the clearance faces and corners remains practically constant.

The tests showed that if the equipment, tools, etc. meet the various requirements then, with mechanical feed, it is possible to continue drilling until considerable chisel-edge wear is observed (greater wear than when drilling with constant pressure), with much greater and more stable drill life. The tests conformed that it is advisable to continue drilling with these drills until wear h_{ch} on the chisel edge reaches a given magnitude.

Before conducting the drill life tests, a study was made of the relationship between drill wear rate, feed rate, cutting speed and drill geometry. Fig. 2 shows wear h_{ch} on the chisel edge of a 1mm-diameter drill plotted against the number of holes drilled with various feed rates s at 4100rev/min, using turpentine as the cutting fluid. As a result of the wear tests, optimum feed rates with constant cutting speed (11-13m/min) were established, and optimum feed rates were then established for the optimum drill-cutting speeds.

Optimum cutting speeds were also obtained for a constant optimum feed rate (Fig. 3-5). As a result of these tests optimum cutting speeds and feeds were recommended for drills of these diameters when drilling steel 45 to a depth of l = 4d, without extraction of the drill (see Table 1).

4. (Continued)

Drill diameter (mm)	Spindle speed (rev/min)	Cutting speed (m/min)	Feed rate (mm/rev)
0.5	7500-8500	11.8-13.4	0.004
0.7	3800-4300	8.4-9.5	0.005
1.0	3500-4500	11.0-14.2	0.006

Table 1.

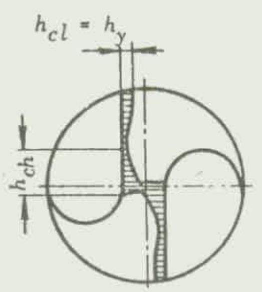


Fig. 1. *Type of wear of drills up to 1mm diameter.*

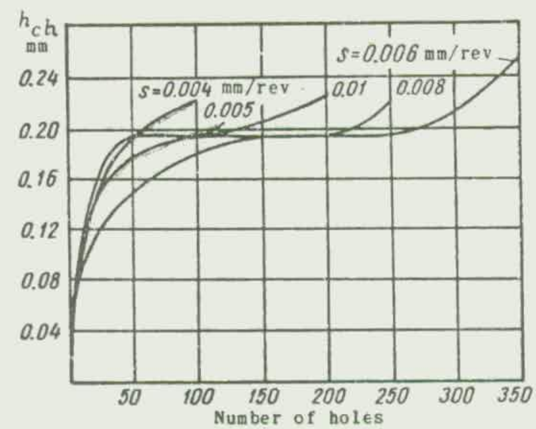


Fig. 2. *Wear of drill chisel-edge plotted against number of holes drilled with various feed rates.*

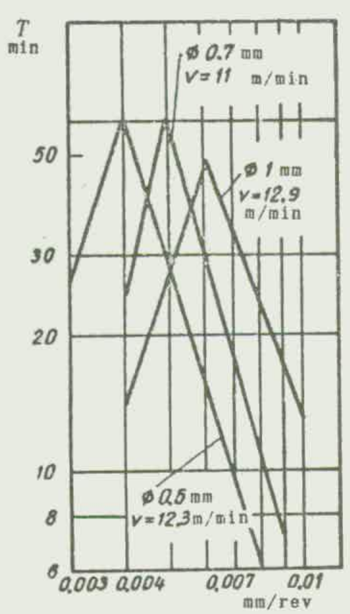


Fig. 3. *Drill life plotted against feed rate.*

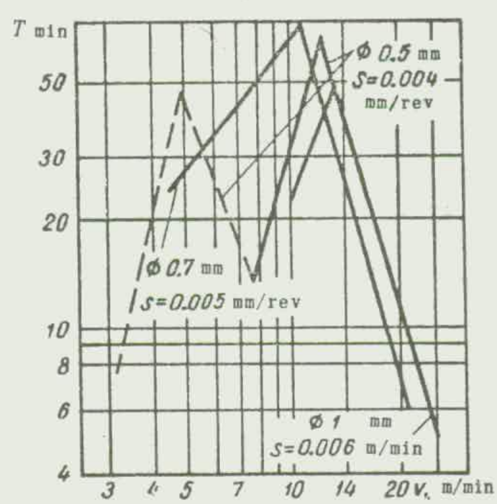


Fig. 4. *Drill life plotted against cutting speed.*

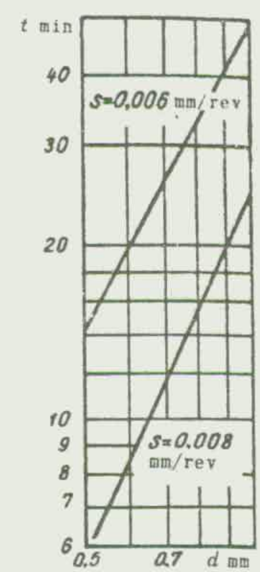


Fig. 5. *Drill life plotted against diameter.*

1. DeBEER, C.

2. THE WEB THICKNESS OF TWIST DRILLS

3. ANNALS OF THE C.I.R.P., 1970, Vol. 18, pp. 81-86

4. Tests were conducted on 14 mm dia. drills with a standard web thickness and with a thinned web. The effect of web thickness on drill rigidity, torque and thrust, and drill life is discussed.

   By using the membrane analogy and the approximation of the drill cross-section shown in Fig. 1, it is shown that a reduction in web thickness does not greatly weaken the drill with respect to torsional loads.

   The stiffness of the drill is affected by the manner in which the thickness of the web is reduced. If this is done by locally reducing the cross-section near the center of the drill the reduction of stiffness is not as great as when the boundaries of the chip groove are moved towards the drill center.

   In order to determine the effect of the web thickness on the torque and thrust forces, tests were conducted with drills having standard and straight webs of varying thickness. The thrust force was reduced up to 40% when the web thickness was reduced to 0.62 mm (on a 14 mm dia. drill) and the torque up to 14%. This is shown in Figures 2 and 3. For standard drills it was observed that web thickness has a parabolic influence on thrust.

   When the web thickness is changed both the drill rigidity and load are affected. Although a loss of rigidity may cause a loss of life, the corresponding reduction in forces may compensate for this effect. Drill life tests were run on drills with a standard web thickness and drills with a 1 mm web thickness. The thin web drills produced more holes than the standard drills. Although the difference in the number of holes was not statistically significant, the test indicated that the thin web did not reduce drill life.

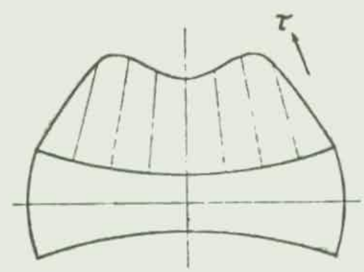
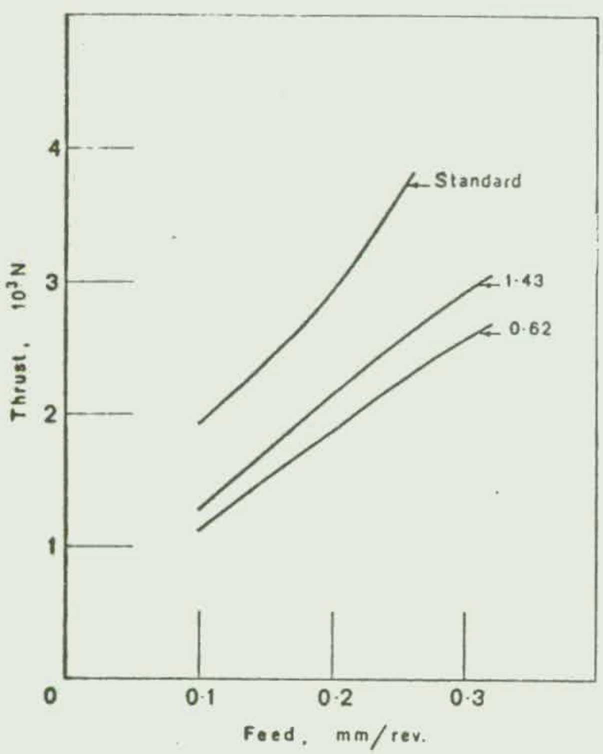
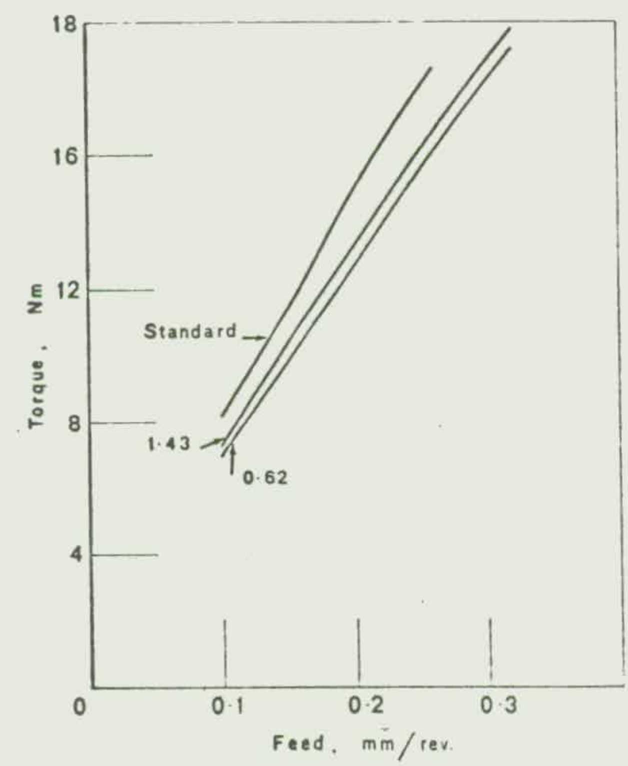


Fig. 1. Shear stress along boundary of cross-section of prismatic bar.



Thrust for standard 14 mm drill compared with thin-webbed drills.

FIG. 2



Torque for standard 14 mm drill compared with thin-webbed drills.

FIG. 3

1. ANONYMOUS

2. SELF CENTERING DRILL FOR ALUMINUM ALLOYS

3. MACHINERY, 1970, Vol. 76, No. 7, pp. 120

4. A twist drill with a fish-tail type point has been studied in Japan and is said to give accurate holes with very small burrs.

   The drill has a 27 degree helix with a 6 degree relief angle on the margin. It is most effective in soft and medium alloys.

FIG. 1. Modified fish tail geometry drill

1. FUJII, S., DeVRIES, M. F., and WU, S. M.

2. AN ANALYSIS OF DRILL GEOMETRY FOR OPTIMUM DRILL DESIGN BY COMPUTER (1) DRILL GEOMETRY ANALYSIS

3. ASME PAPER NO. 70-Prod-5, 1970

4. An analysis of the twist drill point geometry is made so that a digital computer can be used as an aid in designing drills.

   The drill flute and flank contours are analyzed in orthogonal cutting planes, perpendicular to the drill axis, and oblique cutting planes, at an angle other than perpendicular to the drill axis. (Fig. 1)

   The drill point geometry was analyzed in two dimensions by generating a series of cross sections in orthogonal or oblique cutting planes.

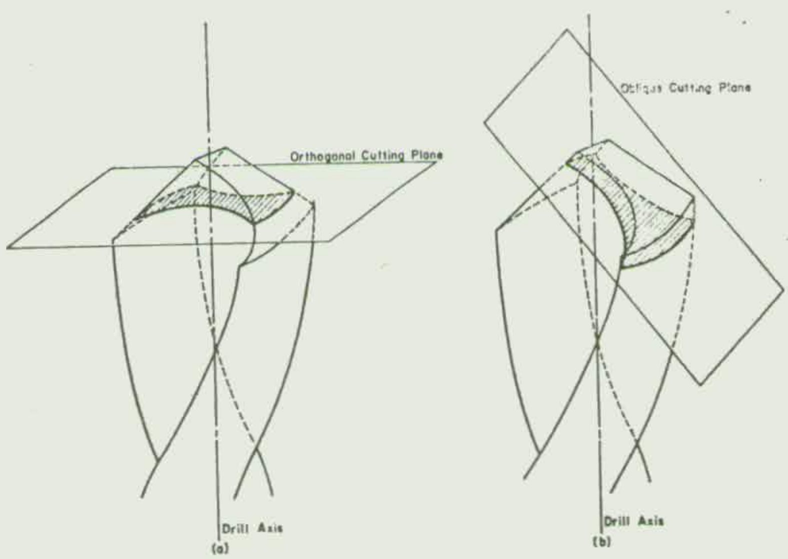


Fig. 1 Orthogonal and oblique cutting planes

1. FUJII, S., DeVRIES, M. F., and WU, S. M.

2. AN ANALYSIS OF DRILL GEOMETRY FOR OPTIMUM DRILL DESIGN BY COMPUTER (2) COMPUTER AIDED DESIGN

3. ASME PAPER NO. 70-Prod.-6, 1970

4. The computer program utilized four design parameters (drill diameter, point angle, helix angle and web thickness) and four grinding parameters (point angle, nominal relief angle, cone semi-angle, and cone vertex location) to design the drill flute contours, generate the flank ellipses and superposition the flute contours and flank ellipses on orthogonal cutting planes.

   A commercially available drill was accurately sharpened and compared with a drill designed by the computer. The comparison was made by laying an end view of the computer designed drill over an end view of the true drill. (Fig. 1)

   The computer program was used to analyze the effect of varying the point angle, helix angle and web thickness.

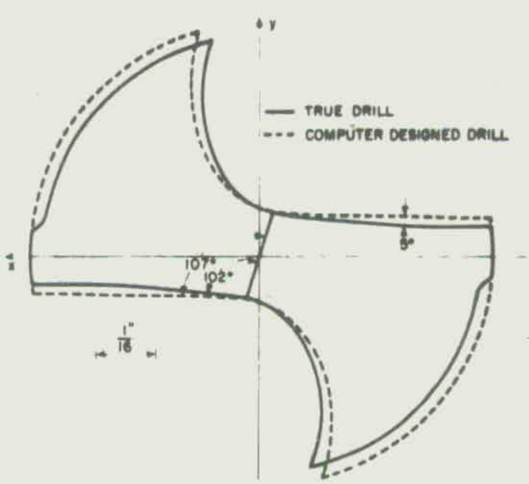


FIG. 1. Comparison of true and computer-designed drill points before rotation

1. McKAY, D. M.

2. USING STANDARD SMALL DRILLS

3. AMERICAN MACHINIST, 1971, April 19, pp. 118-120

4. A comparison of the geometry of a No. 80 (.0135 in. dia.) wire drill and a 1/4 in. jobbers drill is given in Fig. 1. The dimensions of the No. 80 drill have been scaled up to the 1/4 in. dia.

When the No. 80 drill is used, at depths varying from 6 to 18 drill diameters, the heavy web and small flute space present problems of chip removal. To solve this problem it is recommended that drills with a high helix angle be used, the feeds and speeds be reduced, and interrupted or woodpeckering feeding be used.

For drills smaller than 1/16 in. dia., a lip relief of 20 degrees or more should be used. For improved drill life, a surface treatment of ferrous oxide, flash chrome or a nitride case can be used.

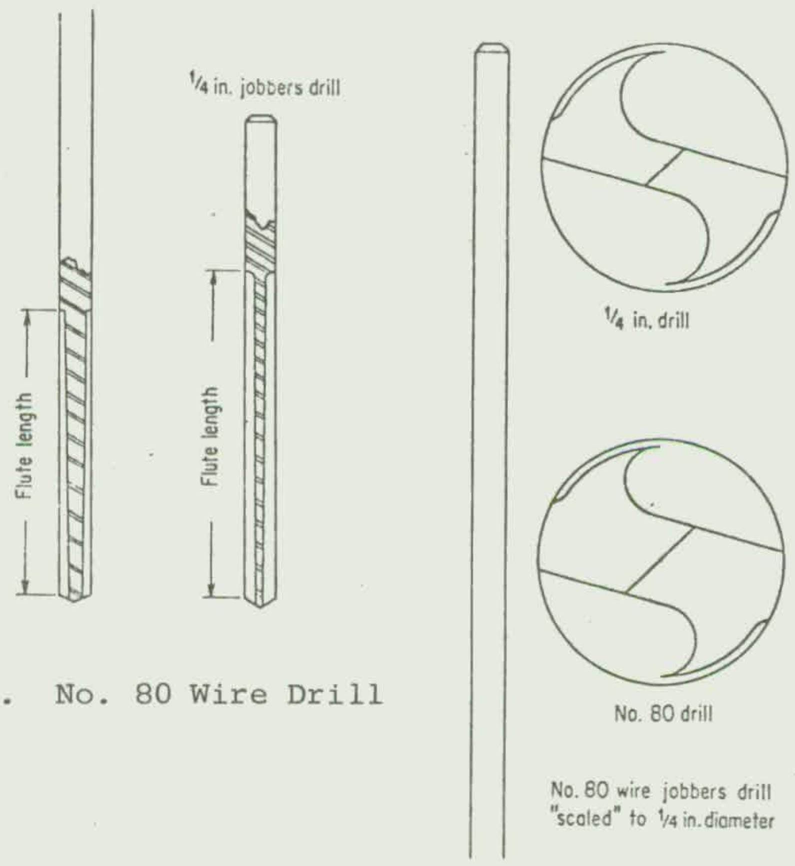


FIG. 1. No. 80 Wire Drill

1. BHATTACHARYYA, A., BHATTACHARYYA, AJIT, CHATTERJEE, A.B., and HAM, I.

2. MODIFICATION OF DRILL POINT FOR REDUCING THRUST

3. ASME PAPER NO. 71-Prod.-12, 1971, pp. 6

4. A method for modifying the chisel edge of a drill into two cutting edges in order to reduce the thrust force is given.

   The modified drill, Fig. 1, has eliminated the high negative rake angle of conventional chisel edge drills as shown in Fig. 2.

   Drilling tests conducted on cast iron indicate that the modified chisel edge drill does not reduce the torque, Fig. 3, although it does reduce the thrust by approximately 50 percent as shown in Fig. 4. It was found that the modified drills were unsatisfactory for ductile materials.

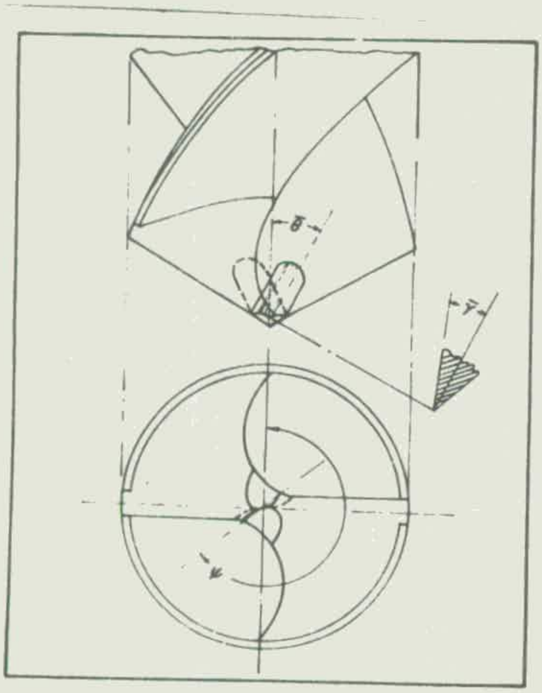


FIG. 1. Drill with proposed modification

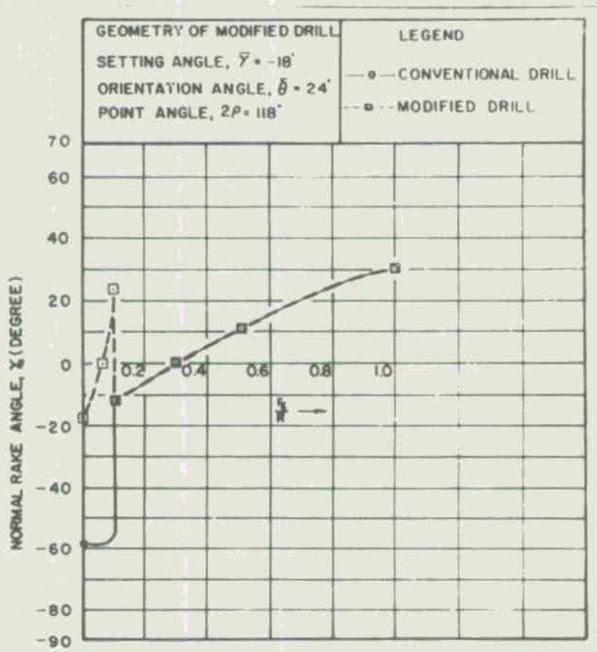


FIG. 2. Distribution of normal rake, in conventional and modified drill

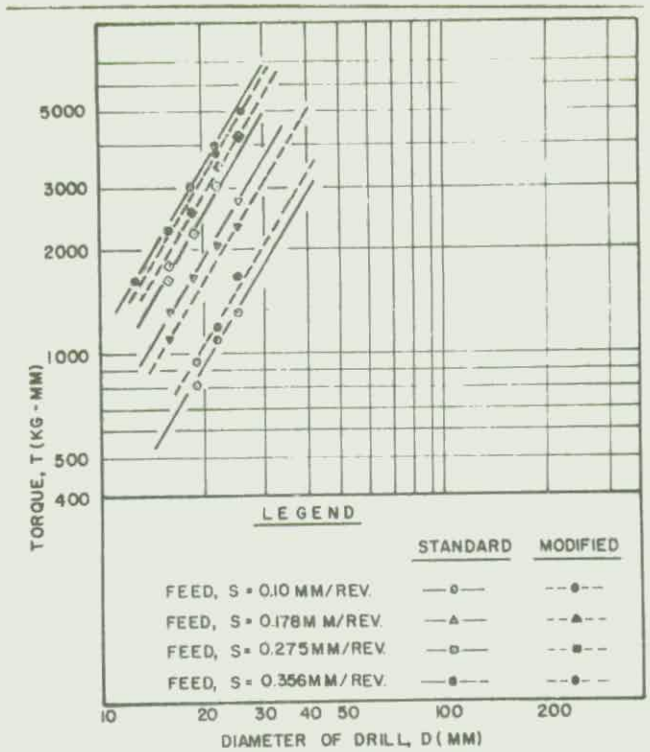


FIG. 3. Log-log plot of torque vs. diameter of standard as well as of modified drill ground at optimum setting angle

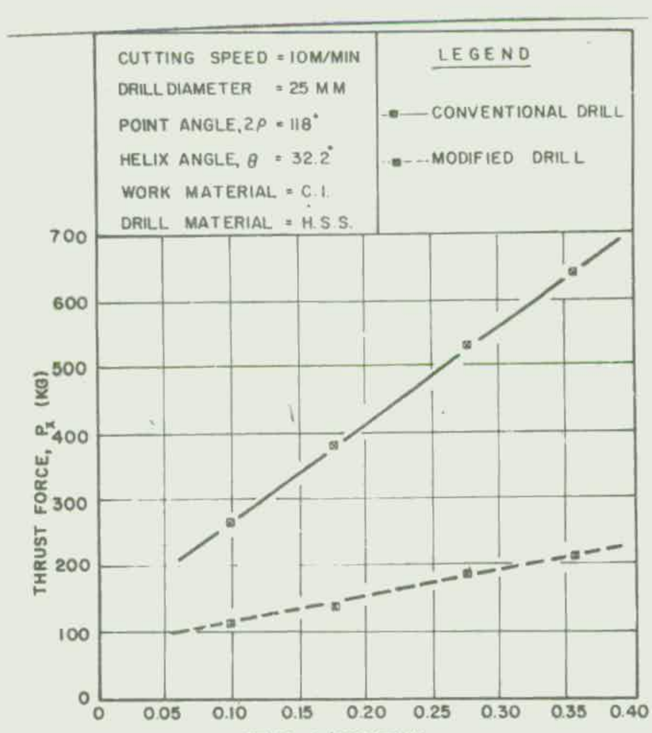


FIG. 4. Plot showing comparison between standard drill and modified chisel drill with optimum setting angle

1. DeVRIES, M. F. and WU, S. M.

2. EVALUATION OF THE EFFECTS OF DESIGN VARIABLES ON DRILL TEMPERATURE RESPONSES

3. ASME PAPER NO. 70-Prod-7, 1970

4. DeVries and Wu investigated the effect of five design and three operating variables on the temperature response of drills. The five design variables are web thickness, at the point, margin width, relative lip height, helix angle and surface condition. The operating variables are cutting speed, feed rate and drilling position.

   They used a replicated two-level factorial design with a total of 512 observations.

   Three of the experimental factors that influence the temperature response of a drill that were investigated were: 1) The transient nature of the drill temperature response. It was found that this had three general areas. A sharp rise in temperature with initial drill penetration followed by a nearly linear increase in temperature. The last area was represented by another sharp increase in temperature if flute clogging occurred as shown in Fig. 1. 2) Location of the thermocouple on the drill flank. It was found that this did not greatly affect the results. 3) Workpiece volume and drill wear interrelationship. The effects of this were "averaged out" by the experimental procedure used.

   The cutting speed and feed rate had the greatest effect on the drill temperature response at a penetration distance of 1 in.

   The design variables that had the greatest effect were the web thickness and helix angle. The drills that were thinned by the technique referred to as "normal notched" had lower temperature response than drills with a helix angle of 14 deg.

   The two factor interactions (Fig. 2) that had the greatest effect on temperature were the helix angle - drilling position and helix angle - surface condition. The 34 deg. helix angle had the greatest reduction in temperature in the conventional drilling position while the surface condition had the largest effect on the drills with a 14 deg. helix.

At a penetration distance of 1.5 in. the effect of a high helix angle and surface coating drilling position became more important. The interaction of helix angle-surface condition and helix angle - drilling position also became more significant.

Flute clogging at a penetration distance of 1.5 in. was analyzed and it was found that a low helix angle (14 deg.), drilling position (conventional), surface condition (uncoated) and feed rate had the greatest effect.

There were three significant two-factor interactions observed. They are feed rate-helix angle, feed rate-drilling position and helix angle-drilling position.

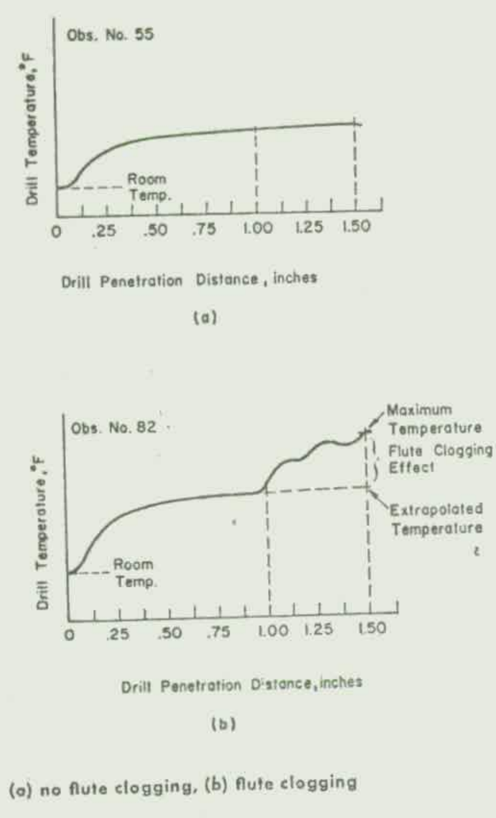


FIG. 1. Experimental temperature versus penetration response

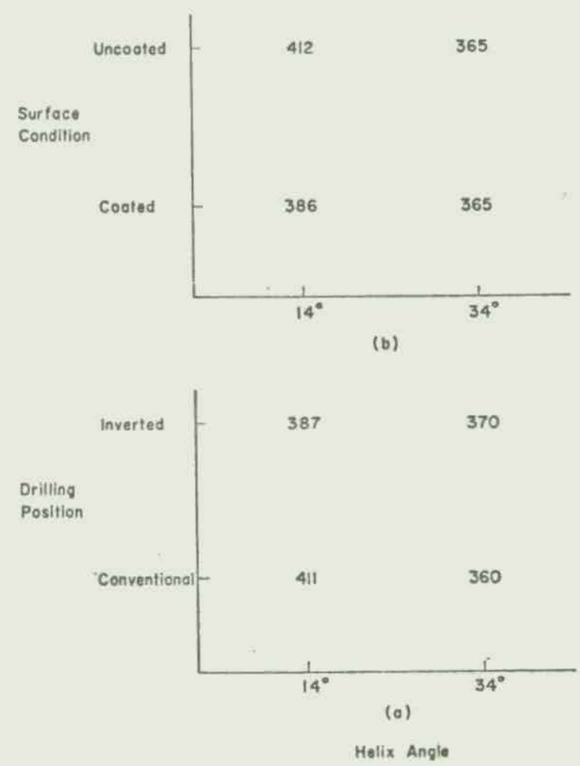


FIG. 2. Temperature response for helix angle versus surface condition and drilling position

1. LORENZ, G.

2. A STUDY OF THE EFFECT OF DRILL SHARPENING AND SIZABILITY OF WORKPIECE MATERIAL ON THE PROCESS VARIABILITY IN DRILLING

3. INTERNATIONAL JOURNAL OF MACHINE TOOL DESIGN AND RESEARCH, Vol. 10, 1970, pgs. 133-141

4. In connection with revision of standard tapping drill sizes, a study was made to find out whether the recommended tolerance grade can be maintained readily and how the process variability is affected by the selection of the drill size, the method of drill sharpening and the sizability of the workpiece material.

The problem has been analyzed in the production of 5/8-18.UNF ordinary nut blanks. The experiments were conducted at the works of an industrial firm according to a simple plan. Two twist drills were machine sharpened in the laboratory and used in production. The hole size distribution was determined for each bar drilled with the test drills. The operator was asked to carry out drill changes according to his normal production practice. The same drills were then hand sharpened by an experienced operator and the experiments were repeated. The statistical parameters, mean size and standard deviation, were analyzed with respect to the variables examined.

The nut blanks were machined on a Traub 42 single-spindle automatic, the drilling speed being v = 185 ft/min and the feed rate s = 0.007 in./rev. The workpiece material was CS1114 free-cutting steel cold-drawn to 11/16 in. hexagonal bright bars. An extreme pressure cutting oil with 2 percent sulphur content was used as cutting fluid. The drill was guided by a center which was cut by its own point when machining the preceding nut.

The standard tapping drill diameter of 14.5 mm was ground to 0.5650 in., this size being 0.0001 in. larger than the low limit of the minor diameter of the nut. The M2-type HSS drills with a helix angle of 27° were sharpened on an Archdale drill sharpening machine (point angle 118°, lip clearance angle 12° and chisel edge angle 112°). In manual sharpening this drill geometry was kept constant as close as possible.

The hole diameters were measured with a nut blank comparator to 0.0005 in. reading accuracy.

The result of the experiments showed quantitatively the necessity of machine sharpening of drills. Figure 1 compares the frequency distributions of hole sizes for the two sharpening methods. These pooled distributions do not take the variation in sizability of the workpiece material into account and indicate that class 2B tolerance can only be readily observed if a non-standard tap drill size is used.

4. (Continued)

This study on the drilling of 5/8-18.UNF nut blanks revealed that

(i) the manual sharpening of drills increases the mean enlargement (oversize) and reduces the actual production tolerance;

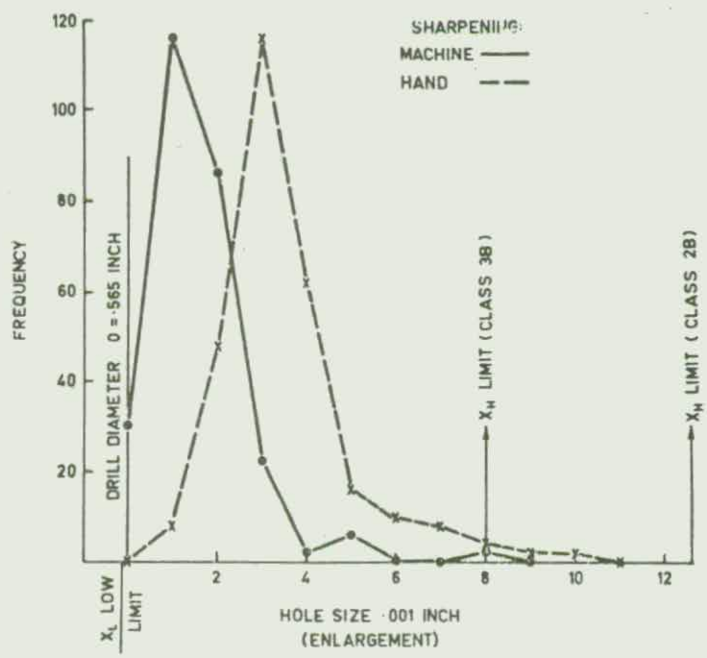
(ii) the sizability of CS1114 free-cutting steel is significantly affected by the carbon and manganese content;

(iii) tolerance grade IT.11 cannot be achieved readily in drilling CS1114 steel;

(iv) standard tap drill sizes reduce the nominal production tolerance by approximately 50 percent;

(v) recommended tap drill sizes cause a considerable loss in production tolerance and do not allow for variations in the sizability of the workpiece material.

The experiments did not yield any information regarding the causes of the heterogeneous variation of the individual bars.



Distribution of hole sizes obtained with machine and hand sharpened non-standard tapping drill.

1. RANTSEV, N. G.

2. FLUTE AND TOOTH GRINDING IN DRILL PRODUCTION

3. MACHINES AND TOOLING, Vol. 41, No. 1, 1970, pg. 44

4. A drill production technology has been introduced involving single-pass grinding of the drill flute and tooth in a completely pre-heat-treated monolithic cylindrical blank. Comparative tests showed that drills produced in this way have much longer life than drills with milled flutes, or drills produced from helical rolled blanks.

Drills are ground in two operations: first the flutes of a batch of drills are ground, then the machine is reset to grind the teeth. The drills are made with tangs, which serve as locating elements during grinding. The post-ground land-width scatter of the drills does not exceed 0.15mm.

Different cutting fluids were tested for use in flute grinding:

1. Water, with 0.5% triethanolamine and 0.3% sodium nitrate, a fluid used successfully in cylindrical grinding and for centerless grinding of drills.

2. Water, with 5% soluble oil, 0.5% sodium nitrate, and 0.3% sodium carbonate additions. This fluid is used in surface and cylindrical grinding.

3. Industrial 12 oil.

1. GRUBETS, Y.

2. DRILLING MANGANESE AUSTENITIC STEEL G131

3. RUSSIAN ENGINEERING JOURNAL, 1970, Vol. 12, No. 12, pp. 77-78

4. Manganese austenitic steel, also knows as Hadfield steel, corresponds to GOST standard steel G13L. Its analysis is: 1.3% C, 13% Mn, 0.5% Si, sometimes also 1% Cr. The steel acquires its characteristic properties after heat-treatment by rapid cooling in water from a temperature of 1050°C. This austenitic steel is relatively soft (HB - 180-220), tough and plastic and has low thermal conductivity.

G13L manganese austenitic steel can be effectively drilled with standard drills tipped with hard-alloys type S1 (standard ISO P10, which corresponds to hard alloy T15K6), S2 (P20 T14K8), U1 (M10 P10 T15K6 and also G1 and H1 (K10, M10 VK3). Test results and practical data show that drills tipped with hard alloy S2 (T14K8) perform best when the drill geometry is as shown in Fig. 1.

The dependences of the drill life T on cutting speed v and feed rate s are shown in Figs. 2 and 3. These relationships can be used to select cutting conditions.

The dependence of the life T (min) of drills 10 to 26mm diameter on cutting-speed and feed-rate is given by the formula

$$T = 2938 \frac{d^{0.48}}{v^{2.6} s^{1.13}}.$$

The cutting speed range is 30 to 80m/min, the feed rate 0.06 to 0.16mm/rev. Recommended values are v = 35-50m/min and s = 0.1mm/rev. At higher cutting speeds and feed rates burrs which are difficult to remove are formed where the drill leaves the hole.

A study of the quality of the drilled holes showed that the surface roughness corresponds to Class 9 surface finish of GOST standard (R_a = 0.2 to 0.4 microns) and the accuracy of diametral dimensions is N9-N11 (A_3 - A_4 to GOST standard) ovality is up to 0.03mm, taper up to 0.04mm on a length of 24mm. No cracks were observed in the hole surface. When drilling with cutting speeds over 60m/min and feed rates over 0.16mm/rev burrs form on the outside edge of the hole. These results correspond to those obtained industrial practice.

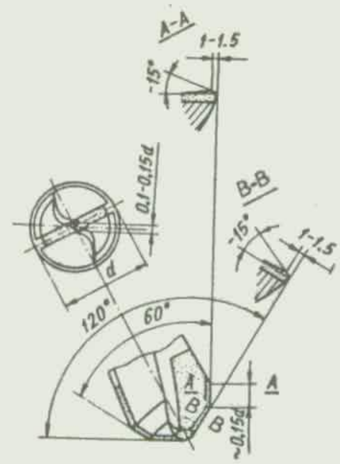


Fig. 1. Geometry of cutting part of drill.

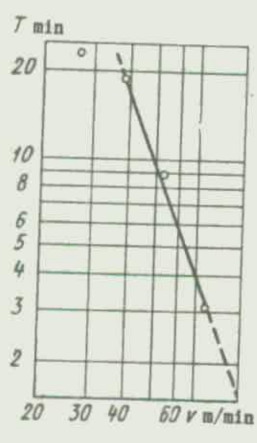


Fig. 2. Influence of cutting speed v on life T: drill diameter 17mm, hard alloy U1 (~ T15K6), s = 0.1mm/rev.

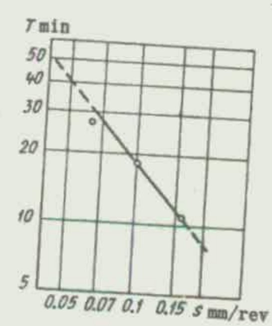


Fig. 3. Influence of feedrate s on life T: drill diameter 17mm, hard alloy U1 (~ T15K6), v = 38m/min.

1. YASHIN, G. G. and PLESHIVTSEV, V. V.

2. DRILLING LIGHT ALLOYS

3. MACHINES AND TOOLING, Vol. 41, No. 6, 1970, pp. 61-63

4. Tests were conducted to improve designs of twist drills for drilling light alloys. The working section of the improved drill is shown in Fig. 1. The main geometrical parameters investigated were the helix angle, tooth and land widths and point geometry. Criteria for assessing efficiency were the cutting force and temperature, the chip-formation process, the surface finish and diameter of the drilled hole.

   In tests to investigate helix angle ω, drills of d = 16 mm diameter with helix angles of $\omega = 15°$, 30° and 45° and a tooth width of b = 0.19d were used. The rakeface geometry corresponded to standard MN 68-65 (chamfer 1.5 mm, rake $\gamma = 15°$, point angle $2\phi = 118°$).

   Before drilling each hole the drill was lightly lubricated with machine oil. Feed rate and cutting speed in the tests were s = 0.43 mm/rev and v = 39 m/min.

   When AL4 aluminum alloy (HB 50) is drilled, cutting force decreases with increasing angle ω (Fig. 2), which can be deduced as due to improved chip-formation. When drills with $\omega = 15°$ are used, build-up of swarf is observed and, with a drilling depth of l = 60 to 80 mm, dense blockages of swarf are formed in the drill flutes, resulting in increased feed force and torque.

   From the nature of the curve it can be assumed that formation of a swarf blockage primarily affects the feed force. Then (after some blockage density is reached), the torque starts to rise. Best results were obtained with drills having $\omega = 45°$. Control tests with drills having helix angles of 35°, 40° and 45° confirmed the accuracy of this assumption.

   To determine optimum cutting edge width, drills with d = 16 mm and b = 0.19d, 0.34d and 0.47d were tested. Holes, 5d deep were drilled in ML5 alloy with s = 0.43 mm/rev feed. At the start of drilling there was no significant difference in torques between different drills (Fig. 3). With $l > 2.5d$, the advantages of drills with narrow teeth become increasingly obvious: they require lower torque. This variation in torque is maintained at all cutting speeds investigated (17-56 m/min).

   Optimum land width f was determined by drilling ML5 alloy with d = 16 mm diameter drills. When drills with wide lands (1-1.2 mm) are used, the material adheres to the lands and the

4. (Continued)

torque and feed force rise. There is increasing adherence of material with each hole drilled, and the drill becomes conical in shape (base of the cone at the shank). The cone removes additional thin layers of metal and the hole diameter increases.

Drills with 0.8 and 0.4 mm wide lands were then tested. The tests showed a considerable reduction in torque (Fig. 4(a)). Feed force is identical for all the drills at the start of drilling; with increasing penetration of drills with narrow lands the feed force decreases (Fig. 4(b)).

As the land width varies, the nature of the cutting zone temperature curve also varies (Fig. 5). When drills with narrow (0.4 mm) lands are used, the most significant drop in temperature (by comparison with other drills) is noted at a drilling depth of 20 mm. Thus, it is advisable to reduce land width to 0.2-0.4 mm.

Drills of this improved design are self-centering in operation. They ensure stable chip-breaking and good swarf-removal and the drill has to be withdrawn less frequently for cleaning. A surface finish within Class 5 limits can be achieved. Tests at three factories showed that drill life is 100-600% higher than can be achieved with standard drills and drills based on MN 68-65.

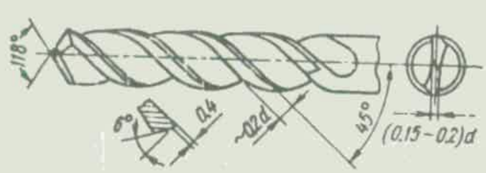


Fig. 1. *Drill of improved design.*

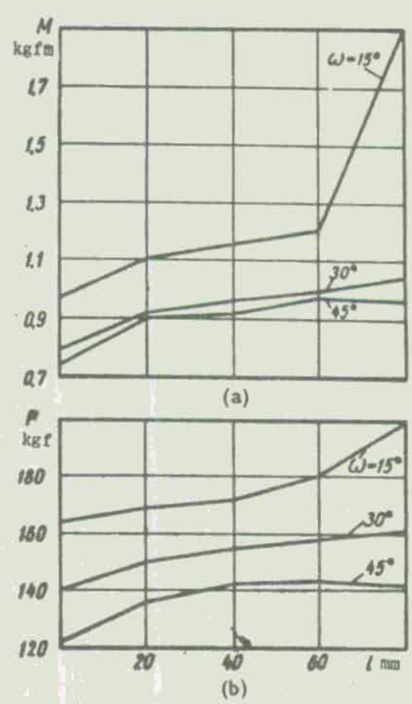


Fig. 2. *Cutting torque (a), and feed force (b), plotted against helix angle when drilling AL4 alloy (l = drilling depth).*

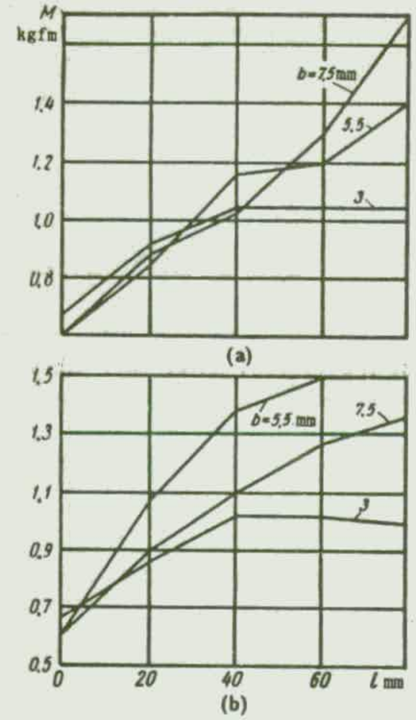


Fig. 3. *Cutting torque plotted against drill tooth width when drilling ML5 alloy (s = = 0.43mm/rev):*
(a), with v = 17m/min;
(b), with v = 56m/min.

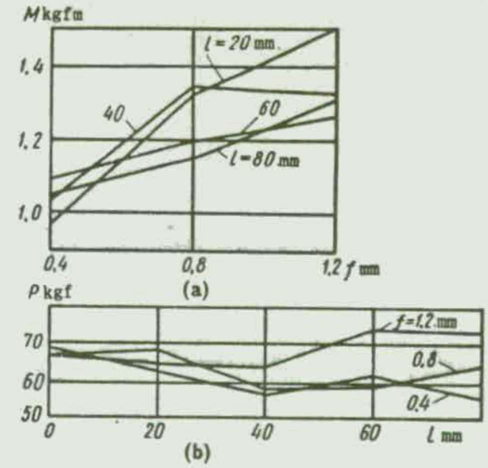


Fig. 4. *Cutting torque (a), and feed force (b) plotted against land width f in the drilling of ML5 alloy.*

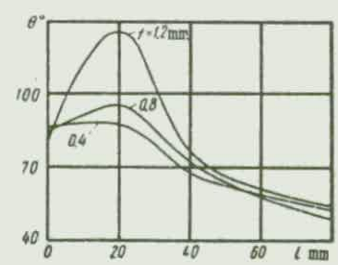


Fig. 5. *Cutting-zone temperature plotted against land width f.*

1. ANONYMOUS

2. SCHLEIFMASCHINE FUR SONDERANSCHLIFFE AN WENDEL- (SPIRAL-) BOHRERN (Grinding machine for special points of twist drills)

3. WERKSTATTSTECHNIK, 1970, No. 8, pp. 481

4. Numerically controlled machines make accurate positioning in drilling possible. The accuracy of drilled holes depends greatly on the drill itself, whether the drill centers itself or walks. A manufacturer of twist drills developed a grinding machine with which the major portion of the chisel edge can be ground with a positive rake angle. This kind of grinding enabled the drill to produce chips not only at the lip, but also at the chisel edge. This helped to eliminate the radial movement of the drill, "walking", and oversized drilling of holes can be eliminated.

   This machine is able to grind drills in the range of 3 to 32 mm in diameter from both cylindrical and conical bar, and the point angle can be varied from 90° to 140°.

1. MALLE, K.

2. WERKZEUGE UND SPANNZEUGE (Tools and Fixtures)

3. WERKSTATT UND BETRIEB, 1970, Vol. 60, No. 12, pp. 754

4. One company in Germany developed a new multi-purpose drill which can be applied to the drilling of stainless steels, hard and brittle brass, aluminum, and also plastic. The drill has a helix angle of 40^{o}, and without a bushing it is able to drill to a depth equal to the length of the flute. A cross-section of this drill is shown in Fig. 1.

   Another company has introduced a three-flute drill of "Deloro-Stellite". The drill was cast and suitable for drilling steel with a hardness greater than HRC51. Therefore, it is applicable for the machining of tools and formed parts. The range of surface roughness obtainable was 1 2 m (RMS).

   It is known that a uniformly distributed force on the lip edge increases the drill life. A drill grinding machine was developed by a company in the U.S.A. which was capable of grinding lip edges which are symmetric and well-rounded.

   A rough machined hole can generally be finished by drilling and counter-sinking. One company in Germany developed a tool and adapter which could be used for both processes simultaneously, whether the tool is stationary or rotating. This tool also had the advantage of being useable in either the forward or reverse feed directions.

1. SPUR, G. AND PROSSKOWITZ, A.

2. UNTERSUCHUNGEN AN ZENTRIERBOHRERN BEIM BOHREN VON VERGÜTUNGSSTÄHLEN (Investigation of Center Drilling in Tempered Steel)

3. ZEITSCHRIFT FÜR WIRTSCHAFTLICHE FERTIGUNG, Vol. 65, No. 2, pp. 51-54, 1970

4. Center drilling offers not only dimensional and geometrical accuracy in sequential operations, but also increased drill life.

   Using a numerically controlled machine tool, an extensive investigation of center drilling was carried out in three different work materials: Ck45 (BHN 194), 37 M_nSi5 (BHN 243) and 42 CrMo4 (BHN 308).

   The N/C program was so made that after every 50 center drillings, the machine tool stopped. The tool wear was measured on the flank wear and these measurements are plotted in Fig. 1. From this figure, it is clear that the material properties are related to the wear during center drilling.

   The relationship between tool life (center drill life criterion = 0.2 mm in flank wear) and center drilling speed for three work materials, is indicated in Fig. 2.

   The center drill life is dependent on drill speed and feed rate as shown in Fig. 3.

   The characteristics of thrust force and torque are described in Fig. 4, in which the following are the changing points: A. Chisel edge is contacted, B. Cutting action of guiding phase is completed, C. Cutting action of 60° sinker is begun, D. Center drilling action is completed. After the investigation of a large number of center drillings, it was found that thrust and torque forces are rapidly increased when center drills reach a failure stage.

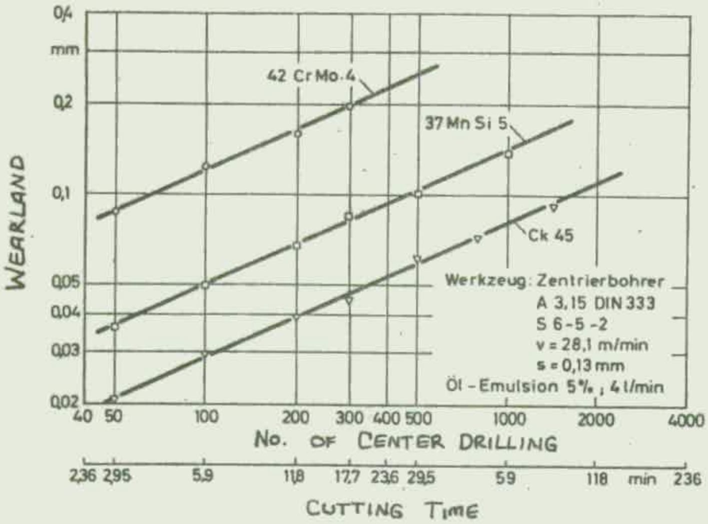


Fig. 1

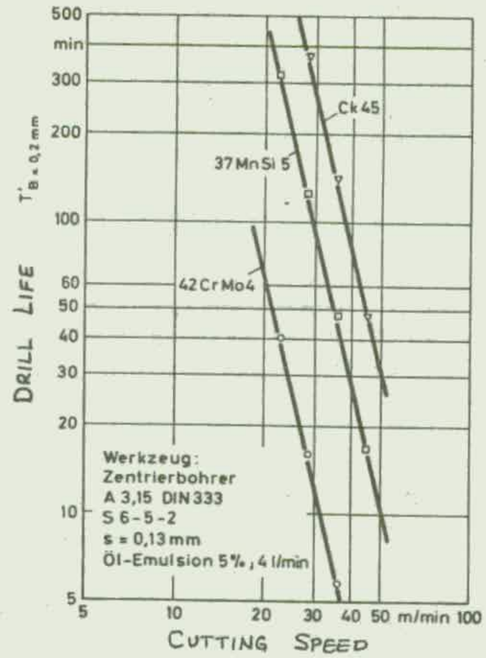


Fig. 2

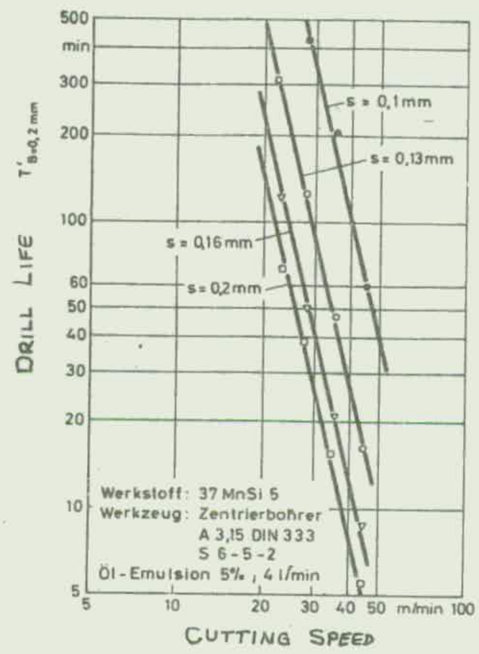


Fig. 3

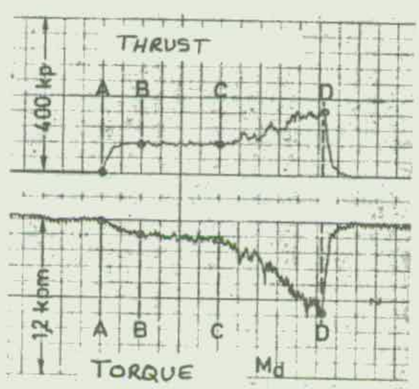


Fig. 4

1. SPUR, G. AND PROSSKOWITZ, A.

2. UNTERSUCHUNGEN AN SPIRALBOHRERN MIT ÖLKANÄLEN BEIM BOHREN VON VERGÜTUNGSSTAHL (Investigation of Drilling in Tempered Steel Using Coolant Hole Drilling)

3. ZEITSCHRIFT FÜR WIRTSCHATLICHE FERTIGUNG, Vol. 65, No. 11, pp. 599-602, 1970

4. The coolant hole drill has the advantage over conventional standard drill geometry in that forced coolant flows through two canals, which are lead through the drill body. This enables sufficient cooling action around the drill and helps eject the produced chips easily to the outside.

   This paper dealt with the result of an investigation of two different cooling methods, one is the conventional method, i.e.,coolant is supplied from the outside, and the other one is through the canals.

   The effect of drilling time on the drill wear by the two different cooling methods is described in Fig. 1. This figure shows that the inside cooling method reduced the tool wear by half compared with the conventional method.

   If the tool life criterion is defined as a flank wear of 0.2 mm, then the relationship between drilled length and drilling speeds, under varied feed rates, is established as shown in Fig. 2.

   The relationship between drill life and feed rate under varied drilling speeds is presented in Fig. 3, where the drill life criterion is a flank wear of 0.2 mm.

   The torque and thrust forces obtained are different by the two cooling methods, and this is shown in Fig. 4.

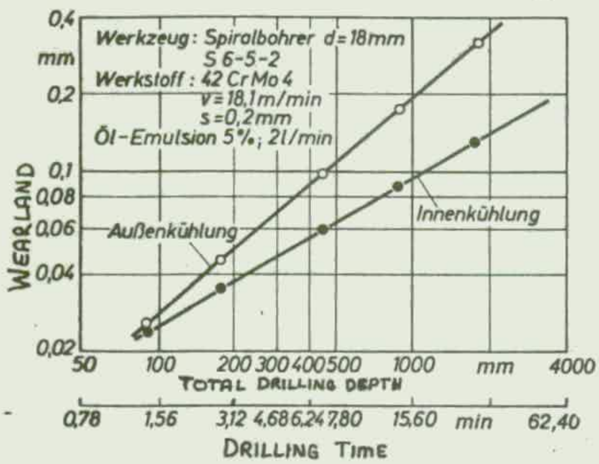


Fig. 1

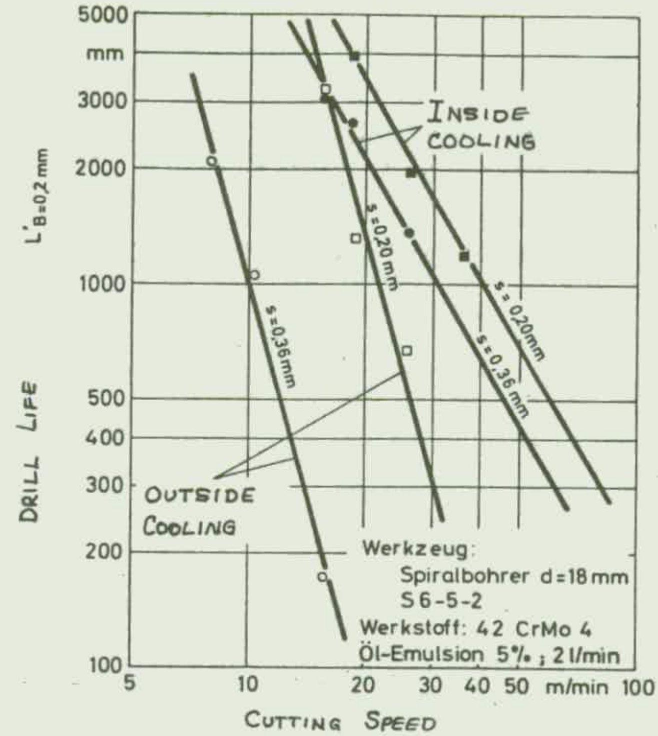


Fig. 2

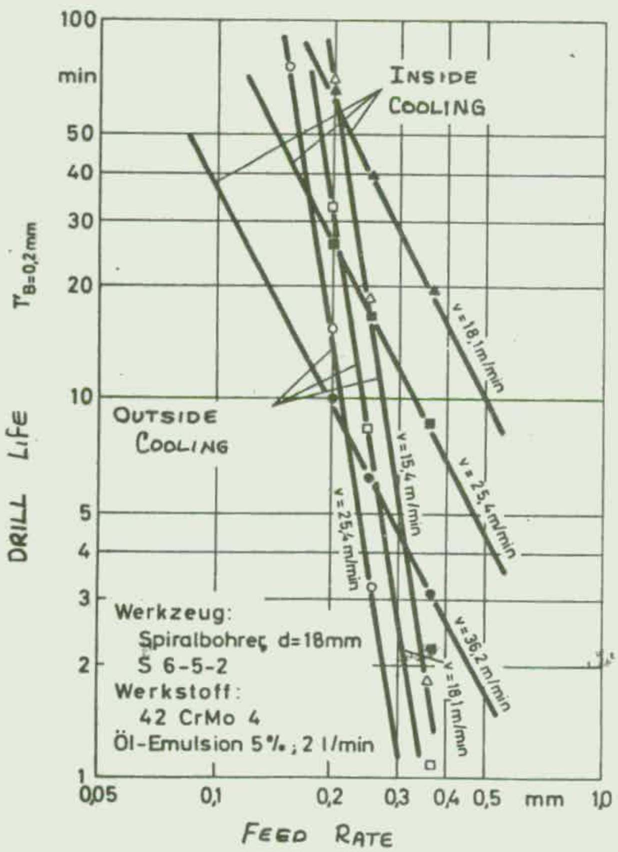


Fig. 3

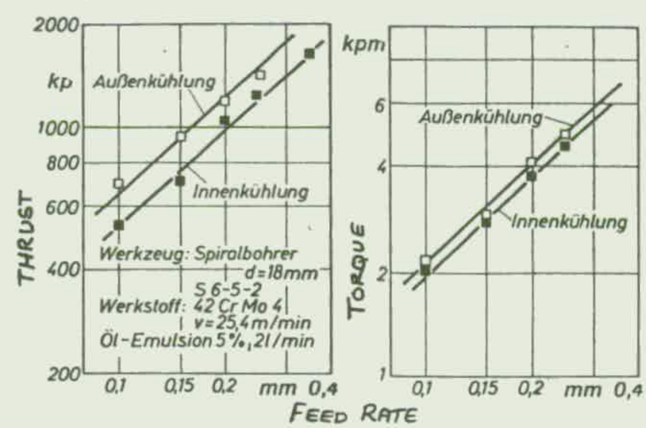


Fig. 4

1. KOCH, U. AND LEVI, R.

2. SOME MECHANICAL AND THERMAL ASPECTS OF TWIST DRILL PERFORMANCE

3. ANNALS OF C.I.R.P., 1971, Vol. 19, pp. 247-254

4. Temperature distribution on the flank of drill points was measured with temperature sensitive paints.

The experiment was designed using factorial analysis. A $3^2 \times 2^3$ factorial design was eventually selected and the level of the factors chosen after a short preliminary investigation as listed in Table 1.

The average responses, d.M.T., obtained for each level of the five factors are given in Table 2. Table 3 shows the analysis of variance pertaining to response d, obtained with standard techniques. Table 4 shows the whole analysis - the entries are the sum over both levels of all the remaining factors of the responses corresponding to the nine treatment combinations considered.

The combined effects of A and B are shown in Fig. 1. A marked correlation between the response d and the power absorbed by the cutting process was obviously expected. The 72 responses were plotted vs. power N, the result being shown in Fig. 2.

TABLE 1. Factors and levels of the $3^2 \times 2^3$ factorial experiment

Factors	Levels		
	0	1	2
A clearance angle, α	6°	9°	12°
B chisel edge angle, ψ	50°	55°	60°
C spindle speed, *n* rev/min	156	200	—
D feed, *a* (mm/rev)	0·125	0·20	—
E pilot hole diameter, ϕ (mm)	0	3·5	

TABLE 2. Average responses showing the effects of single factors

Factors	Levels	Response: d (mm)	Response: M (kg cm)	Response: T (kg)
A	0	3·85	197	155
	1	3·93	199	154
	2	3·49	198	147
B	0	3·55	196	143
	1	3·38	196	144
	2	4·34	201	154
C	0	2·60	200	153
	1	4·91	196	151
D	0	1·45	160	129
	1	6·07	236	175
E	0	5·09	213	256
	1	2·42	183	48

TABLE 3. Analysis of variance of the complete experiment

Source of variation	Sum of squares	Degrees of freedom	Mean squares	$F_{exp.}$
A	262·53	2	131·26	3·06
B	1250·11	2	625·06	14·56†
AB	552·91	4	138·23	3·22*
C	9637·34	1	9637·34	224·55†
AC	7·53	2	3·76	0·09
BC	314·73	2	157·36	3·67*
ABC	364·25	4	91·06	2·12
D	38410·68	1	38410·68	894·97†
AD	201·86	2	100·93	2·35
BD	95·44	2	47·72	1·11
ABC	137·87	4	34·70	0·81
CD	2392·02	1	2392·02	55·73†
ACD	4·49	2	2·24	0·05
BCD	17·80	2	8·90	0·21
E	12880·12	1	12880·12	300·11†
AE	111·58	2	55·79	1·30
BE	520·34	2	260·17	6·06†
ABE	753·81	4	188·45	4·39*
CE	465·13	1	465·13	10·84†
ACE	112·09	2	61·04	1·42
BCE	5·63	2	2·82	0·07
DE	3886·68	1	3886·68	90·56†
ADE	89·68	2	44·84	1·04
BDE	110·43	2	55·22	1·29
CDE	1·51	1	1·51	0·04
ABCD, ABCE, ABDE, ACDE, BCDE, ABCDE	859·09	20	42·95 Δs^2	
Total	73445·65	71		

TABLE 4. Detailed analysis of variance due to factors A and B

Treatment combination	Response (Total)	Sums	Effects		Divisors	Mean Squares	$F_{exp.}$
(1)	275	853	2705	Total			
A_1	312	811	−85	A_L	6	150·52	3·51
A_2	266	1041	−127	A_Q	18	112·01	2·61
B_1	256	−9	188	B_L	6	736·34	17·16†
A_1B_1	309	−10	−57	A_LB_L	4	101·53	2·37
A_2B_1	246	−66	155	A_QB_L	12	250·26	5·83*
B_2	392	−83	272	B_Q	18	513·78	11·97†
A_1B_2	323	−116	−55	A_LB_Q	12	31·52	0·73
A_2B_2	326	72	221	A_QB_Q	36	169·59	3·95
Total	2705					2065·55	

* Significant at 5% level.
† Significant at 1% level.

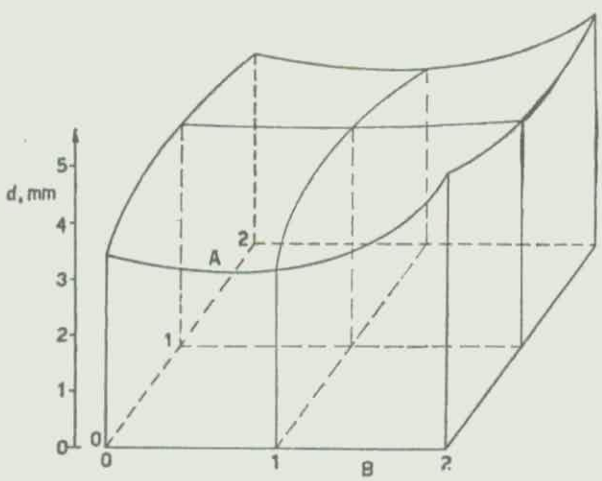


FIG. 1. Effect of factors A and B on response d, showing both linear and quadratic components, and their interaction

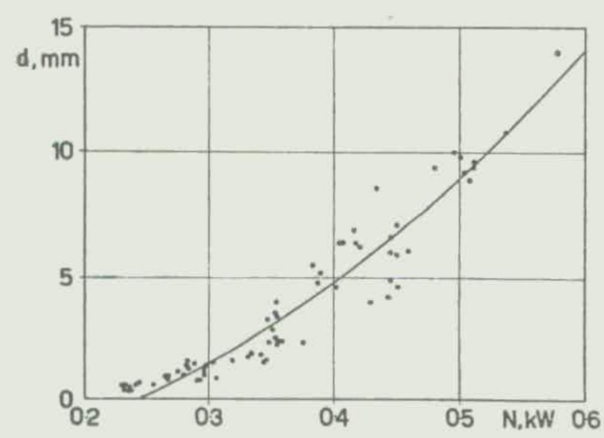


FIG. 2. Response d vs. cutting power N

1. SAXENA, U. K., DeVRIES, M. F., and WU, S. M.

2. DRILL TEMPERATURE DISTRIBUTIONS BY NUMERICAL SOLUTIONS

3. TRANSACTIONS OF THE ASME, JOURNAL OF ENGINEERING FOR INDUSTRY, Series B, November 1971, pp. 1057-1065

4. The backward finite-difference method is used to determine three-dimensional drill temperature distributions. The geometry of the drill was described by (1) approximating the drill as a one-quarter cone and (2) sectioning a true drill point and measuring its profiles. The three-dimensional temperature distributions provided both drill cutting edge and drill flank temperature profiles which were close to prior experimental data and showed improvement over the previous analytical solutions.

CONCLUSIONS

1. A comprehensive three-dimensional drill temperature distribution for both the approximate and true drill geometries is obtained by the backward finite-difference method. The drill cutting edge and drill flank temperature profiles are obtained from the three dimensional temperature distributions.

2. The approximation of the drill shape by a one-quarter cone facilitates the grid network layout and provides drill temperature distributions that are closer to experimental data than previous analytical solutions.

3. The temperature distributions obtained by using the measurements from the true drill geometry provide the best results when compared with experimental data.

1. BHATTACHARYYA, A., BHATTACHARYYA, A., CHATTERJEE, A. B., HAM, I.

2. MODIFICATION OF DRILL POINT FOR REDUCING THRUST

3. TRANSACTIONS OF THE ASME - JOURNAL OF ENGINEERING FOR INDUSTRY, Series B, Nov. 1971, pp. 1073-1078

4. The authors devised a special technique of grinding which modified the chisel edge into a pair of cutting edges by developing two small slots at the chisel edge as shown in Fig. 1. This modification, though, reduces the backing material at the chisel point, and converts it into two auxiliary cutting edges of positive rake angles.

ANALYSIS OF MODIFIED CHISEL EDGE

Inclination Angle. The basic scheme of point grinding, in order to modify the chisel edge of a conventional drill by inclining at a particular inclination and setting angle, is shown in Fig. 2. Fig. 3 shows an enlarged view of the geometry of the chisel edge zone of the modified drill through special grinding using grinding wheels, the sectional profile of the periphery of which is semi-circular.

The inclination angle of modified chisel edge was compared to that of a conventional drill and is shown in Fig. 4. This figure indicates that the inclination angle of the secondary cutting edges at the modified chisel edge has become negative, which was zero along the chisel edge in a conventional drill.

Normal Rake. An enlarged view of the modification scheme of the chisel edge of drills is shown in Fig. 5, where $\overline{\theta}$ and $\overline{\gamma}$ represent the orientation angle and the setting angle, respectively, for the secondary slots of modified drills.

The normal rake at any point can be calculated from Fig. 6 and is given by:

$$\tan \gamma_{nx} = \frac{NN_1}{\ell} \qquad (3)$$

where

ℓ = length of the imagined semicircular cylinder whose diameter equals the width of the grinding wheel.

The variation of normal rake angle along the secondary cutting edges of modified chisel edge in comparison to that along the chisel edge of a conventional drill is shown in Fig. 7, and similar comparative study has been done for the effective rake angle and the results are shown in Fig. 8. From Fig. 8 it is evident that the average effective rake of modified chisel edge has been increased to 0 to 10 deg which was nearly -60 deg in the case of conventional drills.

4. (Continued)

EXPERIMENTAL INVESTIGATION AND DISCUSSION ON TEST RESULTS

While drilling cast iron with these modified drills, torque and thrust have been continuously monitored and the process was repeated for various setting angles of the slots at a particular orientation angle equal to the helix angle, which has been ground in different drills, step-by-step. A typical result is shown in Fig. 9.

Fig. 10 shows the variation of optimum setting angles with respect to their diameter. Cognizance was taken of the variation of helix angles at different diameters.

It has been observed that the above modification could not bring about any appreciable amount of change in torque during drilling cast iron which is indicated in Fig. 11.

However, it reduces the thrust force considerably and the reduction is maximum when optimum setting angle is adopted to the ground slots. Fig. 12 indicates the effect of chisel-edge modification on thrust during drilling cast iron by a modified drill with its optimum setting angle of the auxiliary slots, from which it is evident that the total thrust has been reduced by nearly 50 percent.

The amount of percentage reduction of drilling thrust varies with the size of drills and also with the values of optimum setting angles. The results are shown in Fig. 13.

The effect of orientation angle on reduction of thrust with modified chisel edge incorporating optimum setting angle has been shown in Fig. 14.

It may be seen from Fig. 14 that the thrust is minimum when the orientation angle is close to the helix angle of the drill. However, use of such high orientation angle makes the cutting edges close to the chisel edge weak against brittle fractures. Hence, as a compromise value, it is recommended to use the orientation of the slots at about three fourth of the helix angle.

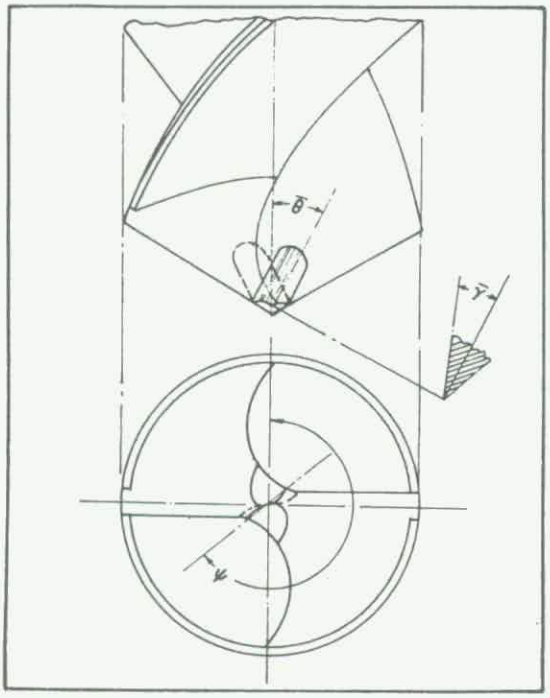


Fig. 1 Drill with proposed modification

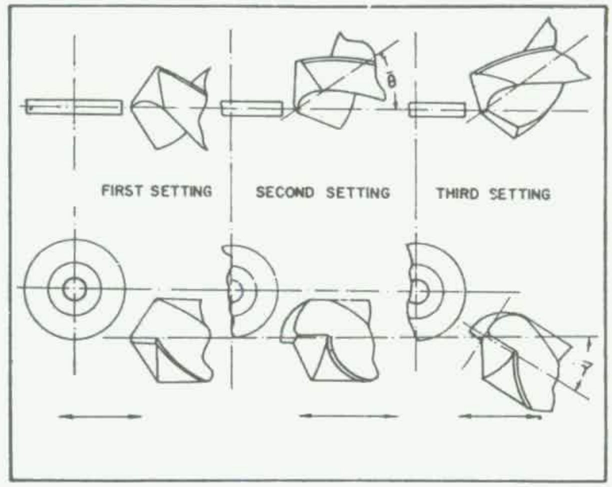


Fig. 2 Setting of drill against grinding wheel for modified geometry

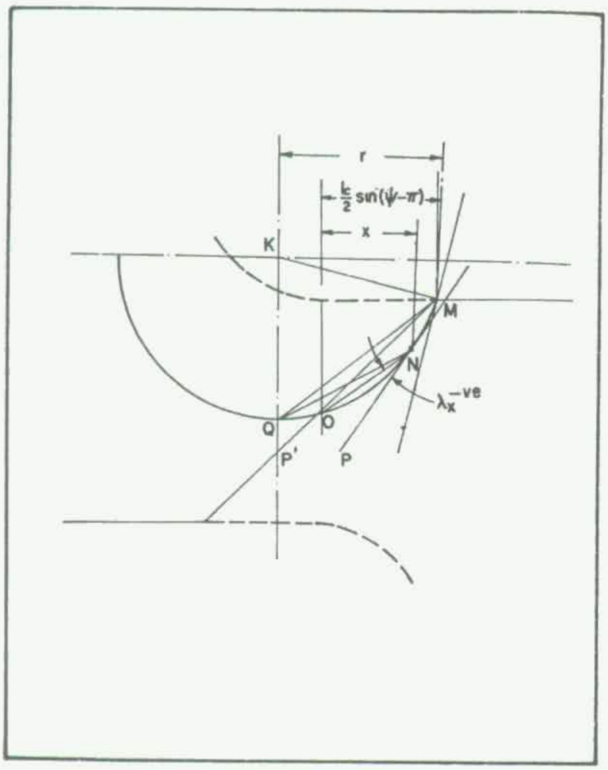


Fig. 3 Enlarged view of the modified chisel edge-zone showing the geometry of inclination angle

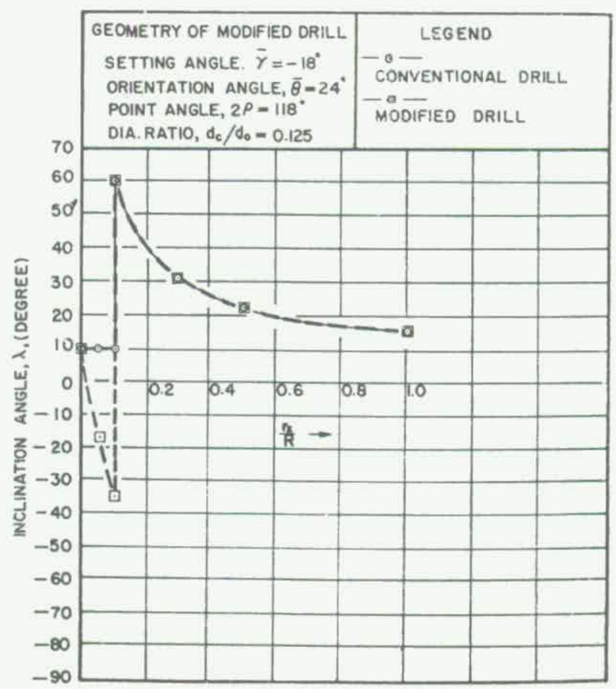


Fig. 4 Distribution of inclination angle λ in conventional and modified drill

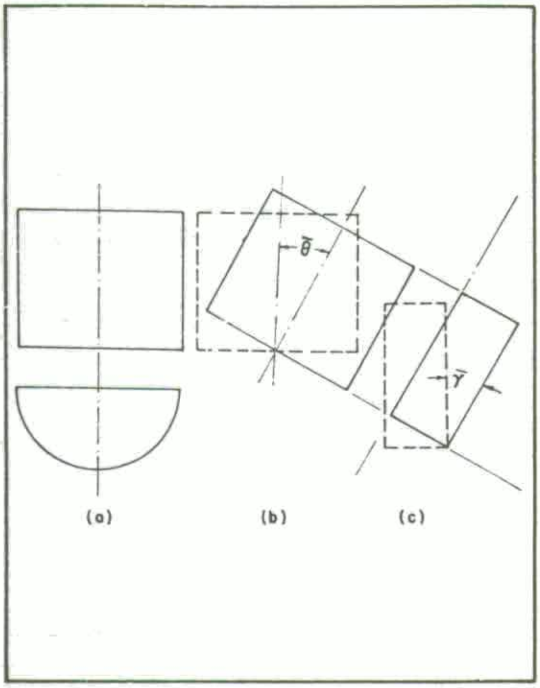


Fig. 5 Scheme for determining rake on secondary cutting edges

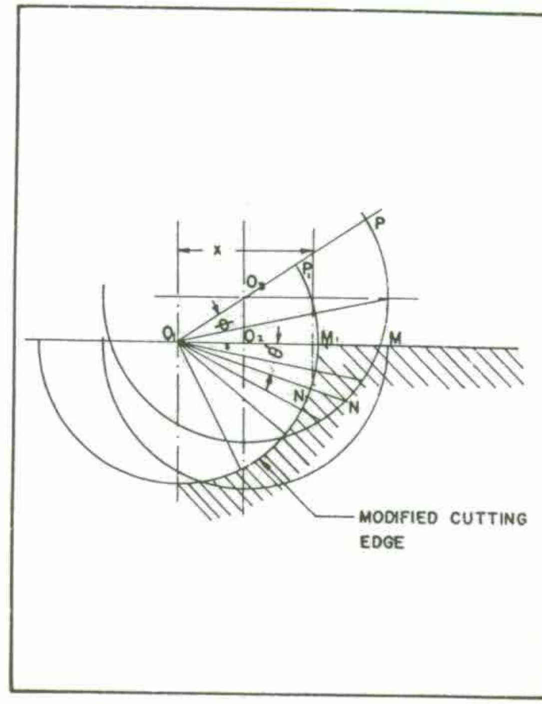


Fig. 6 Evaluation of rake at various points on the secondary cutting edges

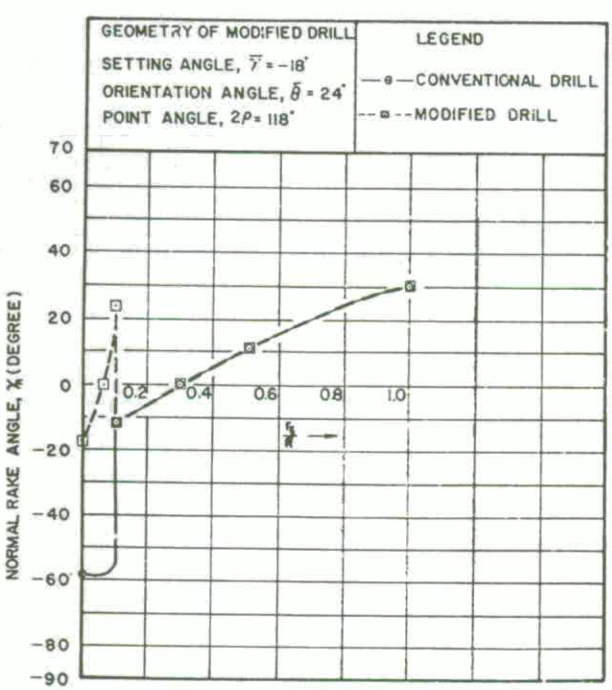


Fig. 7 Distribution of normal rake, γ_n, in conventional and modified drill

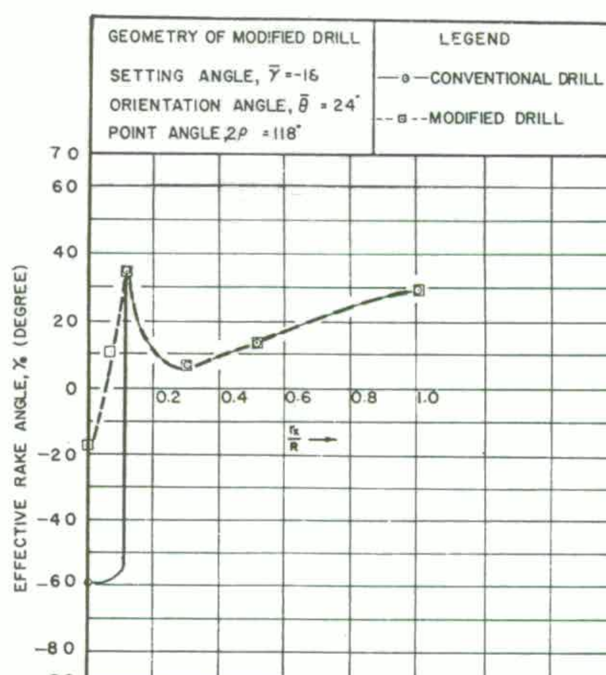


Fig. 8 Distribution of effective rake angle in conventional and modified drills

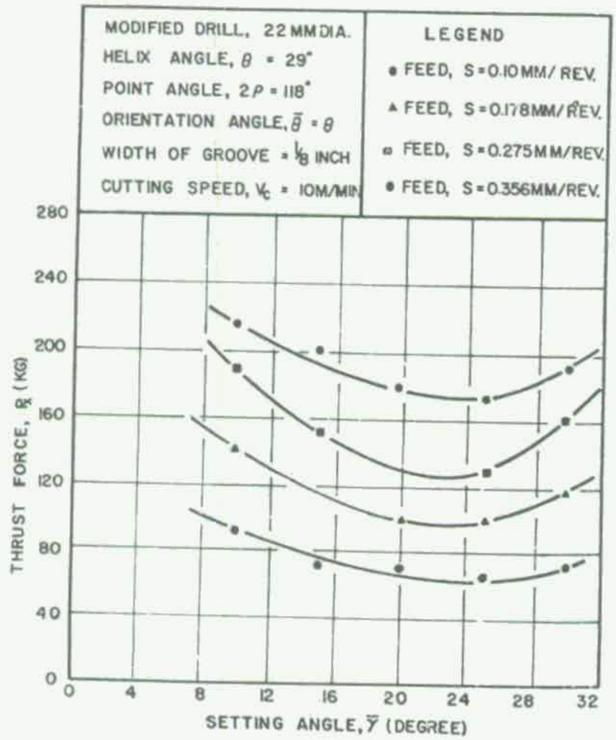


Fig. 9 Variation of thrust while drilling C.I. with setting angle at various feeds for 22 MM modified drills

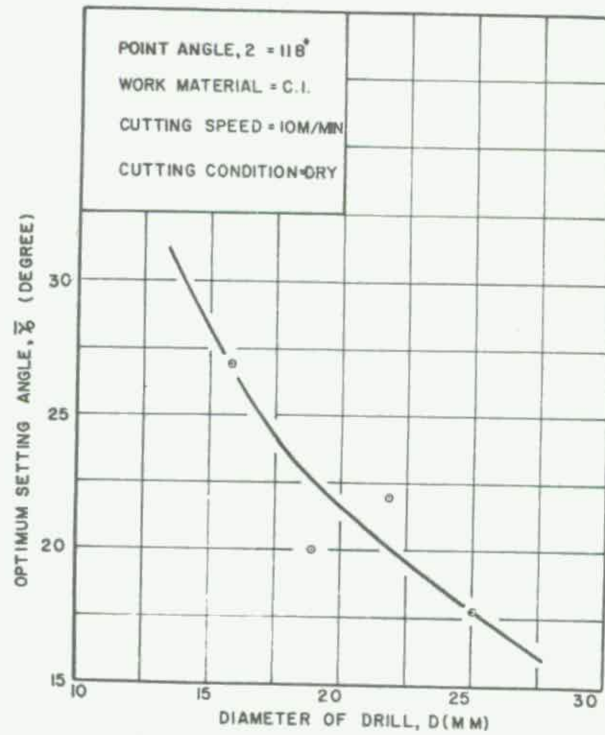


Fig. 10 Variation of optimum setting angle with diameter of modified drills

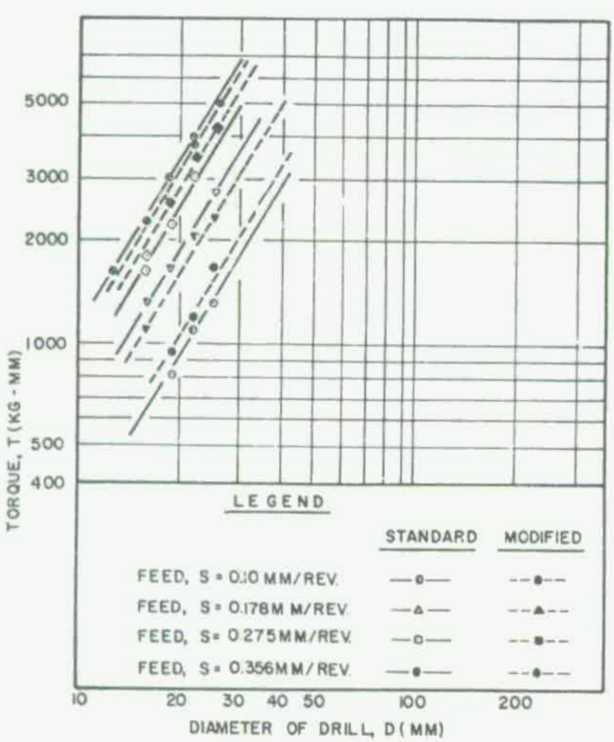


Fig. 11 Log-log plot of torque vs. diameter of standard as well as of modified drill, ground at optimum setting angle

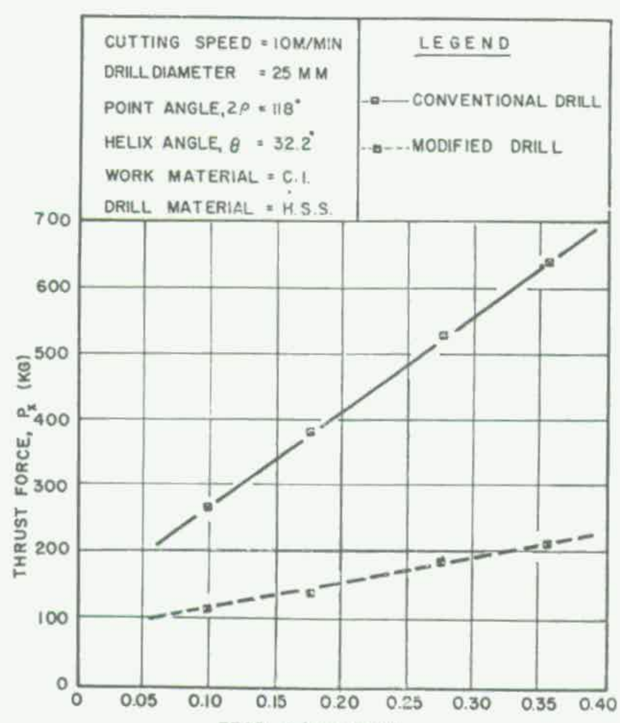


Fig. 12 Plot showing comparison between standard drill and modified chisel drill with optimum setting angle

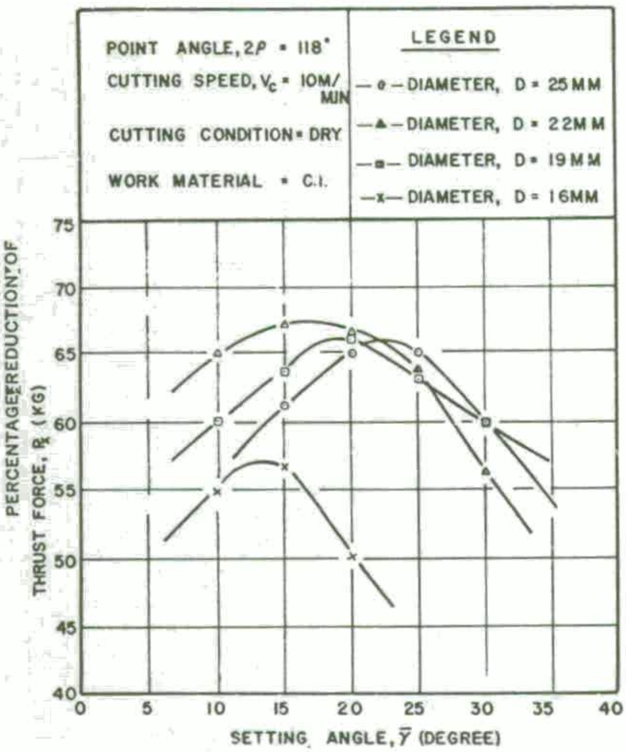


Fig. 13 Percentage reduction in thrust force by modification of the chisel edge

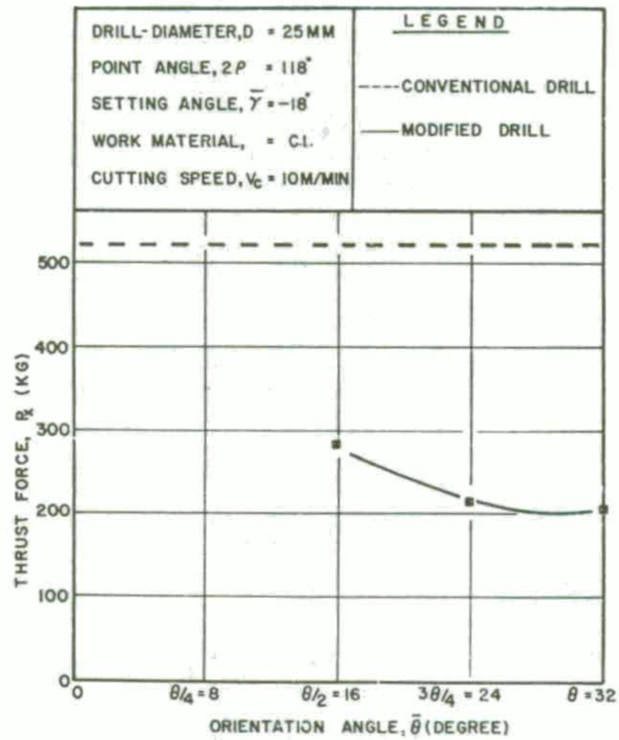


Fig. 14 Effect of orientation angle on thrust force during drilling by a modified drill with optimum setting angle

1. FUJII, S., DeVRIES, M. F., AND WU, S. M.

2. ANALYSIS OF THE CHISEL EDGE AND THE EFFECT OF THE d-THETA RELATIONSHIP ON DRILL POINT GEOMETRY

3. TRANSACTIONS OF THE ASME, JOURNAL OF ENGINEERING FOR INDUSTRY, Series B, November 1971, pp. 1093-1105

4. This paper contains two sections: first, the theoretical analysis of the chisel edge configuration, and second, the effect of grinding conditions on drill point geometry. The analyses are based upon the assumptions of conical grinding, straight cutting edges, and drill point symmetry. In the first section, the chisel edge profile and the chisel edge angle are expressed as a function of the grinding parameters. The relationship between the grinding cone characteristics, viz., the x-coordinate of the cone vertex, -d, and the cone semiangle, θ, is derived based upon a functional relationship for the chisel edge angle. In the second section, the influence of d and θ on drill point geometry is analyzed through an example. The example compares for two drills their overall point configuration, their configuration along the cutting edge, and their configuration along the chisel edge.

Summary. The d-θ relationship provides a way to compare drill point configurations. Based on the example of two sets of d and θ values, the effect of θ on the drill point geometries ground with identical values of k, α_0, and ξ can be summarized as follows:

1. The drill with the larger θ has a larger orthogonal cross section area.

2. The vertical distance between the outer corner and the trailing edge increases with a decrease in θ, although this amount varies depending on the flute design.

3. No difference occurs in the nominal relief angle and the face rake angle along the cutting edge with a change in θ.

4. The clearance angle behind the cutting edge increases with a decrease in θ.

5. The chisel edge profile does not significantly change with a change in θ.

6. The nominal relief angle along the chisel edge remains almost the same with a change in θ.

7. The face rake angle along the chisel edge increases in absolute value as θ decreases.

4. (Continued)

8. The cross section of the drill point at a point on the chisel edge will have a sharper edge as the θ value becomes smaller.

Therefore, a drill point with a larger θ may be stronger but has less clearance space in the flank portion for chip disposal. These contradicting effects imply the existence of an optimum θ value for best drill performance.

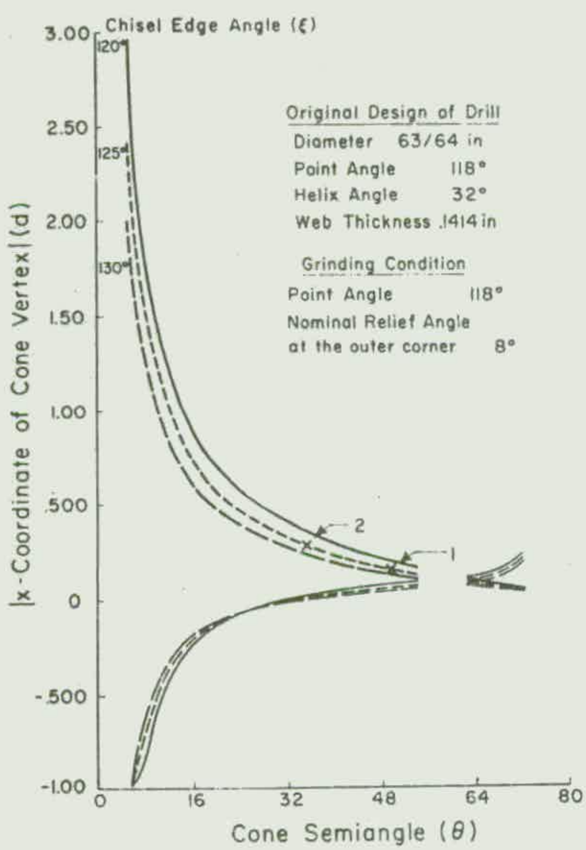


Fig. 2(a) The d-θ relationship for a variation in chisel edge angle

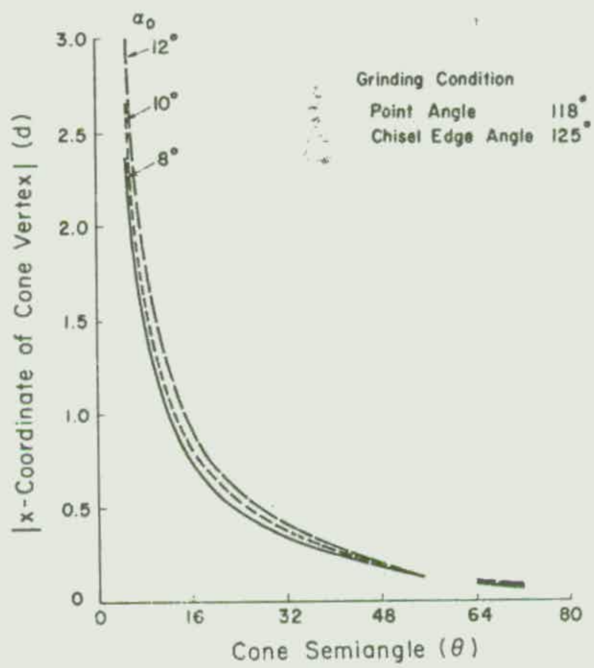


Fig. 2(b) The d-θ relationship for a variation of nominal relief angle at the outer corner

1. EHRENREICH, E. and LENZ, E.

2. DYNAMOMETER FOR DRILLING FORCE MEASUREMENT

3. ASME PAPER NO. 71-Prod-7, pp. 8, 1971

4. A dynamometer for measuring the three components of drilling force was designed and tested. It was designed with three basic parts, a measuring element, a central part for applying the loads and a base.

   The four measuring elements were made in a cross-shaped arrangement. The vertical arms sensed the torque and radial loads and the horizontal arms measured the thrust.

   The cross-shaped measuring elements are mounted on the central part and then attached to the base.

   Drilling tests were conducted with a 14.5 mm diameter drill on En-9 steel at a speed of 18 m/min and a feed of 0.12 mm/rev to test for force variations with drill life. At approximately 65 to 70 holes distorted chips were observed along with a change in the forces. There was a sudden increase in thrust while the fluctuation in thrust leveled out. The radial force also leveled out up to hole number 110 where it begins to fluctuate along with the difference of the maximum and minimum thrust force.

1. KANG, T. H. and CARLESS, J. W.

2. CUTTING FORCE ANALYSIS IN DRILLING

3. SME TECHNICAL PAPER NO. MR71-170, 1971, pp. 1-27

4. The development of dynamometers used for measuring the forces in drilling is reviewed.

   The dynamometer used in this investigation, Fig. 1, similar to the one developed by Pahlitzsch and Spur. This dynamometer has the advantage of being smaller (5¼ in. vs. 9 in. diameter) than the one initially developed. It was made from aluminum and has a collet chuck, Fig. 2, to allow for ease of clamping.

   By observing the torque and thrust diagrams obtained when drilling (Fig. 3) it can be seen that the thrust force reaches a maximum value before the torque. This indicates that the torque and thrust are dependent on different parts of the drill. By drilling in specimens with varying sizes of predrilled holes, it was found that the chisel edge may contribute up to 45% of the thrust and 20% of the total torque as shown in Fig. 4.

   Five different point geometries were tested with each drill producing a different force diagram. It is shown that the exponent for the feed rate varies between 0.8 and 1.3 for torque and between 0.675 and 1.38 for thrust.

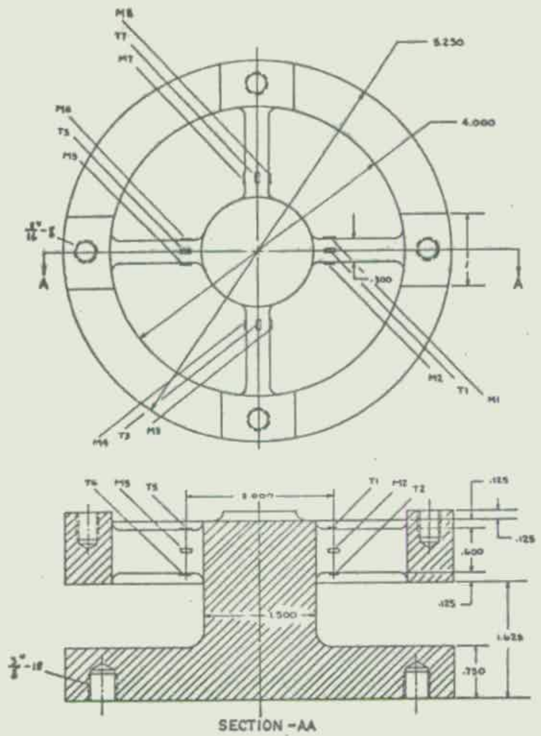


FIG. 1. Two-component dynamometer designed at Michigan Technological University

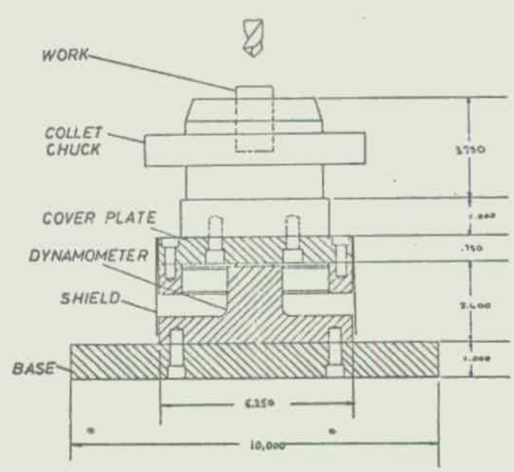


FIG. 2. Schematic illustration of dynamometer and workpiece holder

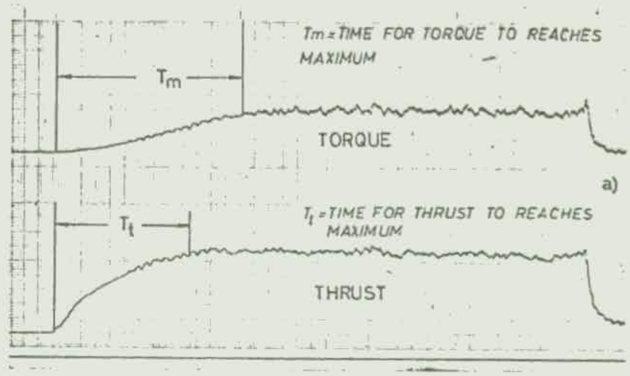


FIG. 3. Diagrams of progress of drilling forces when drilling in solid work

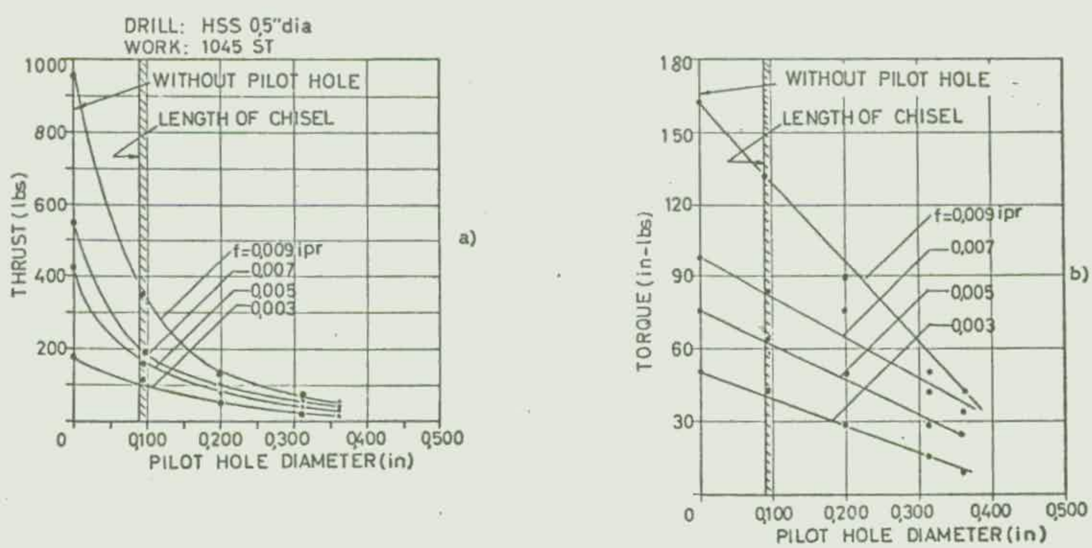


FIG. 4. Effect of pilot hole diameter on drilling forces under various feed rates

1. KOBAYASHI, A. and TSUKADA, T.

2. DRILLING OF MULTI-LAYER PRINTED CIRCUIT BOARD

3. SME TECHNICAL PAPER NO. MR71-202, 1971, pp. 1-8

4. Cemented carbide, K20 drills, 0.5 mm diameter, were used in the experiment. Drills from eight drill companies were inspected for web thickness, chisel edge eccentricity and relative lip height. The results of the drill inspection are shown in Fig. 1. It was found that the eccentricity and relative lip height should be less than 0.01 mm to obtain good holes.

As the drill relief angle increases the quality of the hole decreases, although the thrust force increases for smaller relief angles. The surface roughness increases with increasing point angle although the helix angle had little effect on the holes. For the best holes a point angle of 120 degrees, a relief angle of 20 degrees and a helix angle of 30 degrees are recommended.

The inner surface of the holes is affected by the temperature rise during drilling. In order to minimize the damage due to heat, the feed should be large and the relief surfaces smooth.

The flank wear on the drill when drilling at conditions for producing the best holes is shown in Figs. 2 and 3.

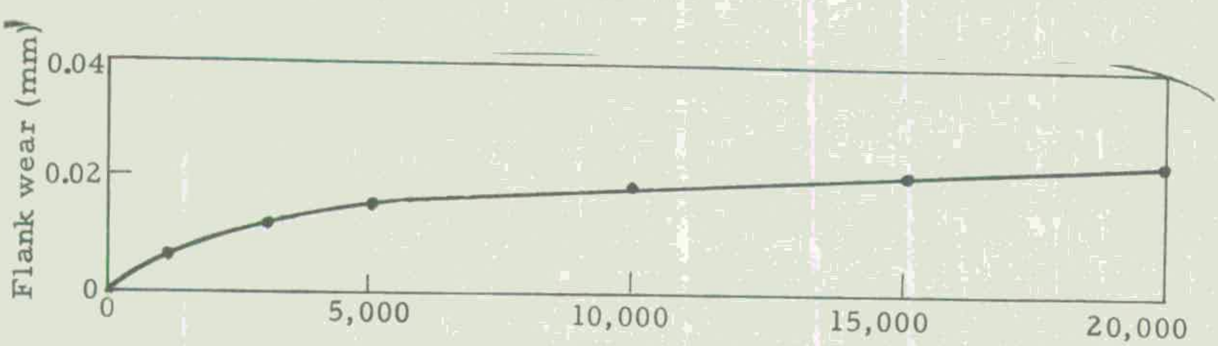


FIG. 2. Relations between flank wear and number of holes

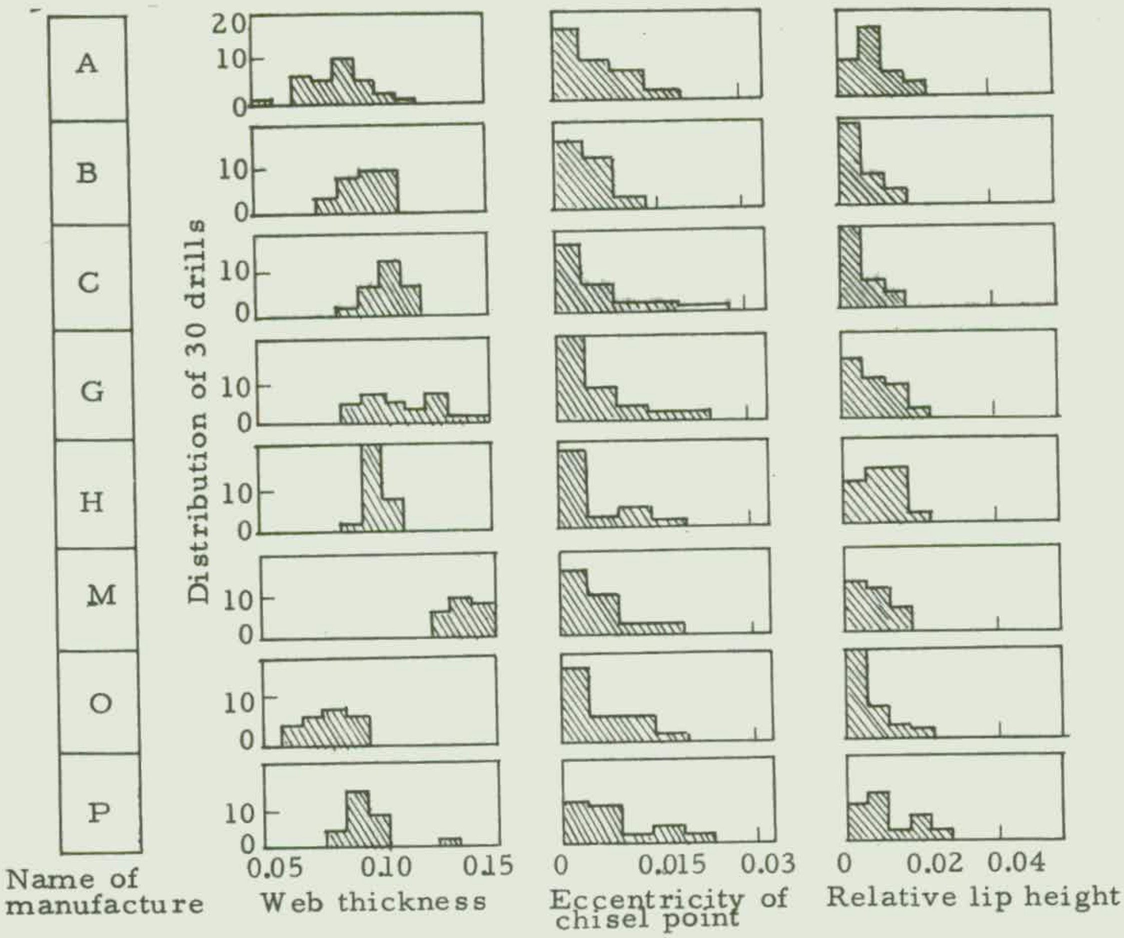


FIG. 1. Accuracy of drills manufactured by several companies

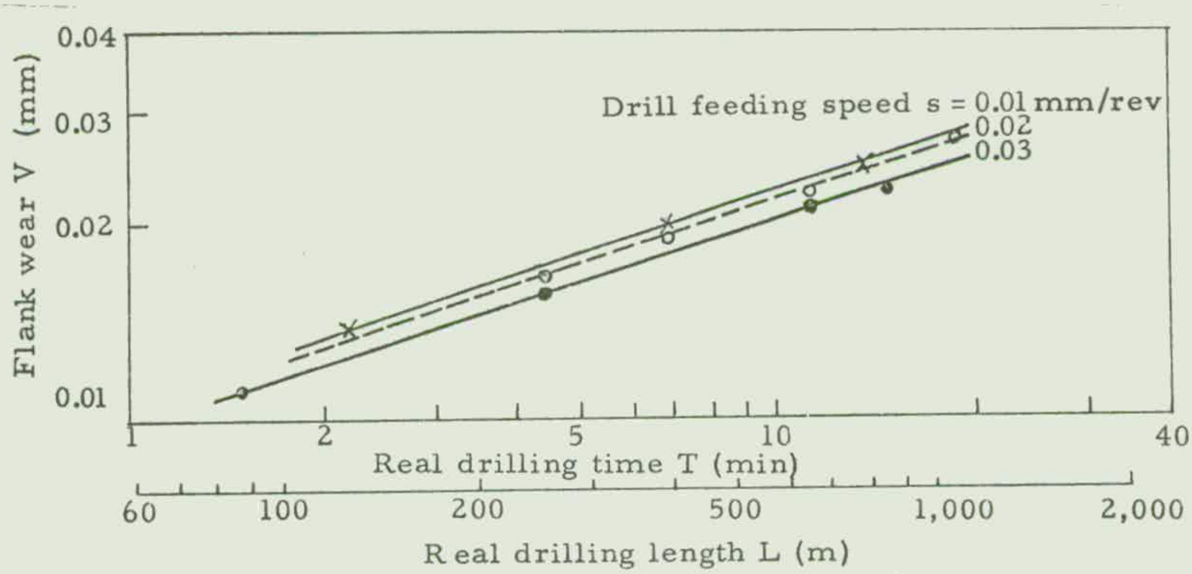


FIG. 3. Relation between flank wear and real drilling time or length

1. PASCOE, LEWIS C.

2. MASS PRODUCING HOLES . . . NOT PARTS

3. MACHINERY, Vol. 77, No. 9, September 1971, pp. 54-56

4. With deep-hole drilling, the principle concern is the amount of web metal between neighboring holes called the ligament. Accurate hole centering is critical, and minimizing drift between the primary (drill entrance) side and the secondary (drill exit) side adds to ligament control. Hole diameters are also critical.

   The best machine for this type of work is a traveling column horizontal-type drilling machine. The column moves along horizontal ways in front of the work, and the head travels up and down the column to position the horizontal spindle in front of the work. The workpiece remains stationary.

   The deep-hole drilling machines are offered with one, two or three spindles. The multiple-spindle designs, particularly the three-spindle machine, were developed to meet the demands of this high production work, demands for larger quantities of holes, shorter lead times and increased productivity.

   The machines' positioning is ideally accomplished by two-axis point-to-point numerical control. On single-column machines, horizontal travel (X axis) varies from 6 to 20 feet and vertical travel (Y axis) varies from 6 to 10 feet. Double-column machines with up to 30 feet of horizontal travel are in operation. These units can operate both heads simultaneously on one large workpiece, or they can operate each head separately on different workpieces. Since all holes are repetitive, the spindle axis does not require tape input.

   Packaged coolant systems supplied with the drilling machines provide high pressure coolant at a constant volume-sulphur-based oils at 1000 psi maximum. A selector switch for gpm setting and a valve for pressure setting can be adjusted for the size of the drill and depth of the hole. A coolant return system moves the oil through a series of filterings (the oil is filtered down to at least 20 micron particle size) and on to the clean oil sump for reuse. A heat exchanger controls oil temperature to a recommended 110F.

1. BAUMGARTEN, ROBERT E.

2. BASIC FACTS ABOUT DRILL BUSHINGS

3. MACHINERY, Vol. 77, No. 12, December 1971, pgs. 50-53

4. Over-size holes and crooked holes are the simple results of a lack of radial support for the drill. And the drill either whips to produce an over-size hole or bends to produce a crooked hole.

   Drill bushings prevent problems like these. The bushings are usually mounted in a jig or fixture so that the part of the drill nearest the tip is supported by the walls of the bushing as the drill begins to cut through material. The bushing is located as closely as possible to the workpiece, with just enough clearance between bushing and workpiece to allow chips to escape.

   The smaller the hole is, the more important the bushing becomes as a guide and locator. On larger holes you can get by without a bushing if tolerances aren't extremely close, because the thickness of the drill required will provide enough rigidity to eliminate whip and resulting out-of-roundness; however, you would still need some kind of fixture or jig to ensure that holes will be in the same location on each workpiece.

   Press fit bushings are available in two basic styles. One is the headless type P; the other is the headed type H. Both are permanently pressed into the job plate or fixture. Their use is recommended for limited production runs, where replacement due to wear is not anticipated during the life of the tooling, or for a single operation, such as only drilling or only reaming.

   Renewable bushings are designed for easy replacement and come in two styles: fixed renewable type F and slip renewable type S. Both are installed as slip fits in liners and are held securely in place by lock screws or clamps.

   Fixed renewable bushings are designed for long production runs and are intended to remain fixed in the jig or fixture until worn out.

   Slip renewable bushings, on the other hand, are recommended for production runs of any length where more than one operation is performed on a hole, such as drilling, followed by reaming and counter-boring.

   Liners are permanently pressed into the jig plate or fixture to provide precision mounting holes of correct slip fit for renewable bushings and to prevent wear of soft jig plates

4. (Continued)

caused by frequent removal and replacement of renewable bushings.

Liners are available in two basic ANSI styles: headless type L and headed type HL.

Headless and headed liners are similar to headless and headed bushings in both their advantages and their limitations.

In most instances, the bushings used for potted or cast-in-place installation are of the grooved diamond knurled type or the grooved serrated type, so that once potted or cast in place, the bushing becomes a permanent part of the tooling.

Circuit board drill machines require still another type of bushing. These bushings vary for each type of machine and are categorized by the type of machine involved: Digital, Edlund, Electro-Mechano, Excellon, Leland-Gifford, Nawide, Palomar, Rapidril and Tektronics.

Tungsten carbide bushings should be considered only for extremely long production runs. These bushings last much longer than standard hardened steel bushings and can save up to 80 percent on a cost-per-hole basis.

Tungsten carbide bushings are available in types already covered: headless press fit and headed press fit, fixed renewable and slip renewable bushings, and circuit board bushings.

<u>Note</u>: Material also presented by author in the article, "Selecting and Installing Drill Bushings," Manufacturing Engineering and Management, Vol. 70, No. 2, February 1973, pgs. 40-42.

1. STAROV, N. A. and KOTLIKOVA, A. L.

2. BETTER QUALITY TWIST DRILLS

3. RUSSIAN ENGINEERING JOURNAL, Vol. 51, No. 4, 1971, pp. 60-63

4. An analysis of the manufacturing process for taper-shank twist drills at the Frezer works has shown that an asymmetry of the cutting edges, and a displacement of the centre line of the core, relative to the centre line of the working part of the drill, can arise because of the following: 'beat' of the outer diameter, relative to the centre line, as a result of grinding on a centreless grinder; lack of alignment of the centre lines of shank and of the cutting part; sharpening errors.

   The Bauman MVTU University has developed a manufacturing technology for h.s.s. 15 mm-diameter drills with the following geometry: $\alpha = 16°$, $2\phi = 90°$ and $\omega = 35°$. This drill geometry is optimal only for drilling gray cast-iron.

   The drill stock was ground on a circular grinder instead of on a centreless grinder, which ensured a beat of the outer diameter of the blank, relative to the centre line, limited to 0.03 mm.

   The swarf flutes and backing-off sections were milled in one pass on a modernized spline milling machine with a special hobbing cutter. This operation ensures the production of symmetrical cutting edges and a constant thickness of the core along the length of the cutting section. The working part of the drills was ground in two operations, preliminary and finish grinding, so that any barrel shape at the beginning of the cutting section is eliminated and the surface finish of the lands was improved.

   The backing-off faces were sharpened by a method of grinding in two planes, with a tolerance on the axial beat of the cutting edges of up to 0.03 mm.

   Tool life tests conducted with the new drills showed that this geometry gave a life 3.4 times longer than drills manufactured by conventional means.

1. VINOGRADOV, A. A. et al

2. DRILLING HIGH-STRENGTH IRONS WITH CARBIDE-TIPPED DRILLS

3. RUSSIAN ENGINEERING JOURNAL, Vol. 51, No. 8, 1971, pp. 87-88

4. Tests were conducted on high-strength iron containing 3.5% C, 1.3% Si, 0.5% Mn, 0.6% P, 0.02% S, 0.15% Cr, 3.3-4.0% Ni and 0.3-0.6% Mo. Specimens in the form of 60mm thick segments were cut from calender roll blanks as used in paper-making machines. Hardness varied from HB 510 to HB 330 from the periphery to the centre. Drills with helical cemented-carbide (VK8) heads were used to drill blind holes 2.5D deep. The cutting fluid was a mixture of 70% paraffin and 30% machine oil delivered to the cutting zone at a rate of 4-5lit/min.

On the basis of tests to determine optimum geometry, an asymmetrical cutting section form was adopted (see Fig. 1). The drill was considered to require regrinding when the wear on the peripheral sections of the secondary cutting edges measured on the clearance face side reached 0.7mm for drills up to 12mm diameter and 0.9mm for drills over 12mm.

When drilling irons of HB 350 and 400 Hardness, the curve of drilling speed v against drill life T in logarithmic co-ordinates is a broken line (Fig. 2); this is probably because of the difference in wear at different cutting speeds. Fig. 2 also shows drill life T plotted against feed rate s. Drill life T is plotted against diameter D in Fig. 3.

On the basis of the particular relationships (Fig. 2 and 3) it was possible to derive a general equation for determining cutting speed:

$$v = \frac{C_v D^z}{T^m s^y}. \qquad (1)$$

Values of constant C_v and the powers in equation (1) depend on the hardness of the iron and are determined from the equations:

$$m = 3{,}44-7{,}1\cdot 10^{-3}\ \text{HB};\ y = 1{,}54\ m;$$

for drills up to 10.5mm diameter

$$C_v = 2{,}2\cdot 10^{-5}\left(\frac{HB}{350}\right)^{18{,}5};\ z = 5{,}6\ m.$$

4. (Continued)

for drills over 10.5mm

$$C_v = 4.4 \cdot 10^{-3} \left(\frac{HB}{350}\right)^{18.5} ; \; z = 3{,}1 \text{ m}.$$

Values of the constant and powers in equation (1) are given in Table 1. Recommended cutting speeds and feeds for iron having the hardness (HB 360) most often encountered at the points where calender rolls are drilled are given in Table 2.

The effect of cutting speed on axial force P and torque M is shown in Fig. 4. The relationship between axial force, torque, feed rate, drill diameter and hardness of the iron was also investigated.

As a result of these tests it was possible to derive the following equations for determining P and M at the start of the tool life period:

$$P = 24 \cdot 10^{-3} \; v^{-0{,}24} S^{0{,}49} D^{0{,}92} HB^{1.63} \text{ (kgf)}; \qquad (2)$$

$$M = 7{,}13 \cdot 10^{-3} \; v^{-0{,}27} S^{0{,}69} D^{1{,}75} HB^{1{,}20} \text{(kgf.cm)}. \qquad (3)$$

To determine P and M at the end of the life period, the values obtained from formulae (2) and (3) should be multiplied by the following coefficients: $k_p = 1.45$ and $k_m = 1.35$ for drills up to 10.2mm diameter; $k_p = 1.65$ and $k_m = 1.45$ for drills above 10.2mm.

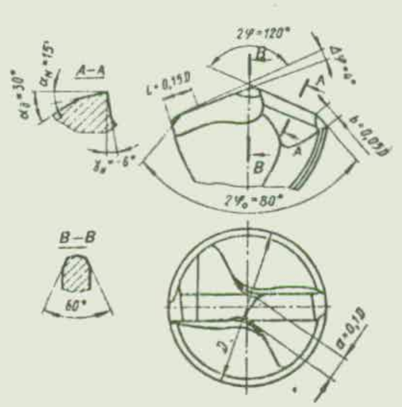


Fig. 1.
Drill geometry.

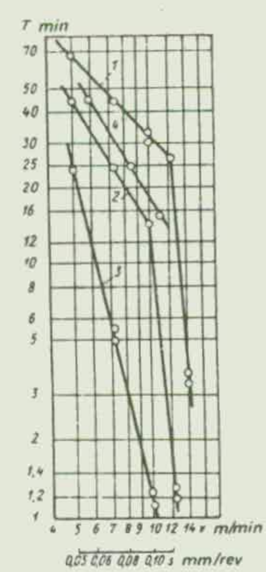


Fig. 2.
Life T of 12mm diameter drills plotted against cutting speed v and feed rate s in the drilling of iron:
1 – s = 0.084mm/rev, HB 350;
2 – s = 0.084mm/rev, HB 400;
3 – s = 0.084mm/rev, HB 450;
4 – v = 10m/min, HB 365.

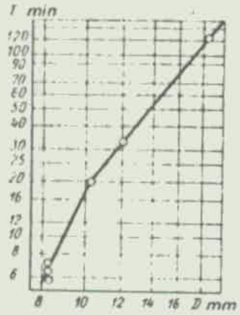


Fig. 3.
Drill life T plotted against diameter D when drilling iron of HB 355 hardness with v = = 10m/min and s = 0.084mm/rev.

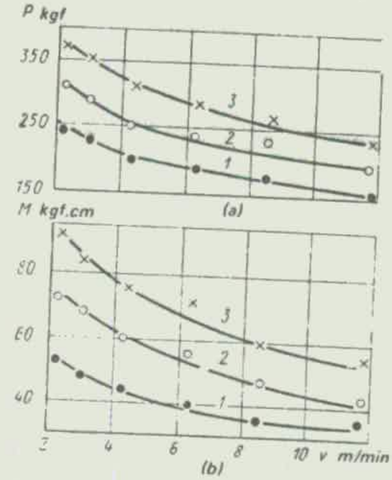


Fig. 4.
Axial force P (a), and torque M (b), plotted against cutting speed v when drilling iron of HB 410 hardness with 10.2mm diameter drills:
1 – s = 0.037mm/rev;
2 – s = 0.058mm/rev;
3 – s = 0.084mm/rev.

1. MIKHAILYUK, E. A., et al

2. DRILLING SMALL DIAMETER HOLES IN HARDENED STEELS

3. RUSSIAN ENGINEERING JOURNAL, Vol. 51, No. 9, 1971, pp. 95-98

4. To determine drilling conditions ensuring the production of holes in these steels with a surface finish not below Class 5 at an economically sound tool life, tests were carried out on drilling through-holes of diameter 3-10 mm in hardened steels 30KhGSA (σB, tensile strength = 120 kgf/mm^2) and 30KhGSNA (σB, tensile strength = 170 kgf/mm^2). The 30KhGSA steel was drilled on a vertical drilling machine, and the 30KhGSNA steel was drilled on a vertical milling machine, because of its greater rigidity; a 10% emulsion (consumption 8 litre/min) was used as coolant. The tests were on two-land drills made of steel R18 (h.s. steel), four-land drills made of steel R18, and also drills with brazed tips of hard alloy VK8 and monolithic drills of VK15M cemented-carbide. The high-speed drills had a tip angle $2\phi = 120°$, a helix angle $\omega = 30°$, and a relief angle of $\alpha = 12°$; the cemented-carbide drills had an angle $2\phi = 120°$; $\gamma = 0°$, $\alpha = 8°$ and a relieved point. During the tests it was found that wear of the drills is accompanied by adherence of chips on the lips and lands, which was particularly intensive during wear on the clearance faces of the peripheral part with $h_b \geq 0.3$-0.35 mm. Under these conditions the rate of wear of the drill increases sharply (Fig. 1), wear spreads to the tip and land, as a result of which a large part of the drill has to be cut away during regrindings in order to restore its cutting properties.

The tests showed (see Fig. 1) that when drilling 30KhGSA steel the life of four-land high-speed drills and even more so of cemented-carbide drills is much greater than for the two-land high-speed drills, this being due to the greater rigidity of the four-land drills and higher red hardness of the cemented-carbide drills. During the drilling of 30KhGSNA steel, the life of cemented carbide solid drills was 50% greater than for drills with brazed tips, despite the fact that VK8 alloy has higher wear resistance than VK15M alloy. In addition, the monolithic drills displayed a much greater operational reliability; with roughly 40% of the test drills with brazed tips, the latter chipped and broke off without reaching a wear of h_{bo} taken as the blunting criterion, which is due to thermal stresses and micro-cracks produced during the brazing and sharpening of the tips, and also the close proximity of the brazing region to the cutting zone.

4. (Continued)

The relationships between life and cutting conditions were only determined for solid cemented-carbide drills and, for purposes of comparison, for standard two-land high-speed drills.

The relations obtained (Fig. 2) show that the cutting speed exerts a unique influence on the life of cemented-carbide drills. The life of these drills only increases if the cutting speed is reduced to a particular value (in our case about 10 m/min); any further reduction of cutting speed produces a sharp reduction of life. This is caused by the development of intensive vibrations of low frequency and large amplitude, which are typical of low cutting speeds.

The influence of cutting speed and feed is illustrated by the relationships shown in Fig. 3. As can be seen, drilling with a feed s = 0.005-0.09 mm/rev ensures the production of holes with a finish not inferior to a Class 5 surface finish ($R_z \leq 20$ μm) at practically any value of the cutting speed v; drilling with a feed of s = 0.15 mm/rev only gives the required finish at v < 15 m/min.

To elucidate the influence of lubricants and coolants on the finish of the holes produced, drilling tests were carried out using 10% emulsion, NIAT liquid, 'sulphofrezols', drying oil, spindle oil and kerosene. The tests showed that the greatest effect in terms of reduction of the roughness of the holes is achieved using sulphofrezol and spindle oil.

Using the data obtained we have calculated cutting conditions which give holes with a surface finish not below Class 5 in drilling hardened steels (Table 1).

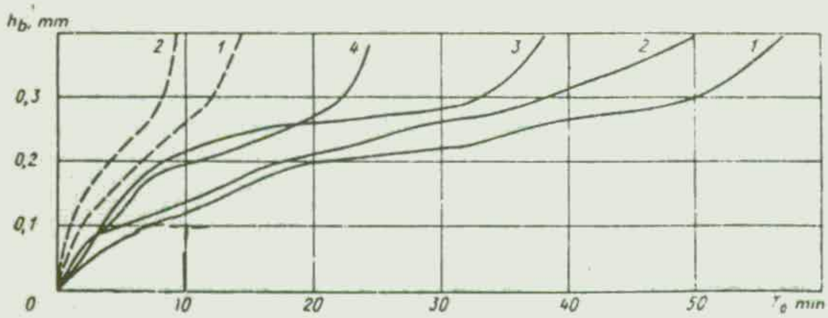


Fig. 1.
Dependence of wear h_b on operating time T_0 of different designs of drills for drilling 6mm dia. holes in steel 30KhGSA (solid curves) and steel 30KhGSNA (dashed curves):
1 – solid drill of VK15M cemented-carbide.
2 – drill with brazed tip of VK8 cemented-carbide;
3 – four-land drill of steel R18;
4 – two-land (standard) drill of steel R18.
Conditions for machining steel 30KhGSA cutting speed v = 10m/min; feed s = 0.07mm/rev; for steel 30KhGSNA: v = 18m/min, s = 0.05mm/rev; coolant, 10% emulsion.

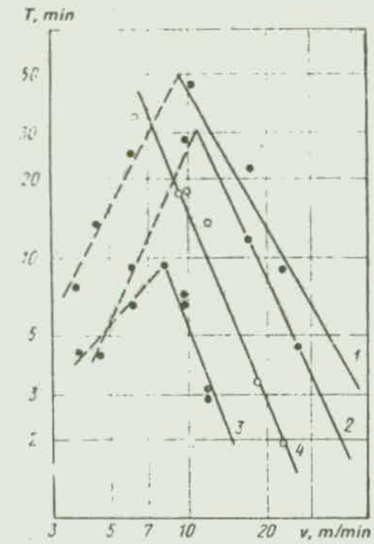


Fig. 2.
Dependence of drill life T on cutting speed v for drilling holes in steels 30KhGSA and 30KhGSNA with 10% emulsion coolant:
1 – solid drill of VK15M cemented-carbide, steel 30KhGSA, hole diameter d = 5mm, feed s = 0.07mm/rev;
2 – ditto, but steel 30KhGSNA, s = 0.05mm/rev;
3 – ditto, but d = 4mm;
4 – drill of steel R18, steel 30KhGSA, d = 5mm, s = 0.07mm/rev.

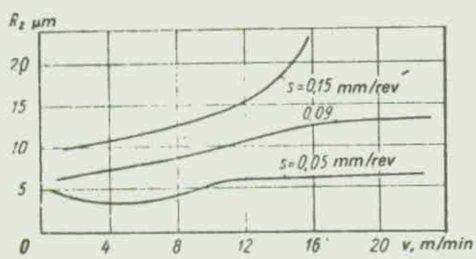


Fig. 3.
Influence of cutting speed v and feed s on height of irregularities R_z on the surface of holes produced in steel 30KhGSA with a drill of steel R18 (d = 5mm; h_b = 0.15mm; 10% emulsion coolant).

Table 1

Drill diameter d (mm)	Life T (min)	Drill material for drilling: Steel 30KhGSA, Steel R18: s (mm/rev)	Steel 30KhGSA, Steel R18: v (m/min)	Steel 30KhGSA, Cemented-carbide VK15M: s (mm/rev)	Steel 30KhGSA, Cemented-carbide VK15M: v (m/min)	Steel 30KhGSNA, Cemented-carbide VK15M: s (mm/rev)	Steel 30KhGSNA, Cemented-carbide VK15M: v (m/min)
3	5	0,06	6,3	0,04	21	0,04	9
		0,08	5,7	0,05	15,7	–	–
		0,1	4,7	0,07	10	–	–
5	7	0,06	8,5	0,04	40	0,04	15,5
		0,08	7,6	0,05	29	0,05	10,6
		0,1	6,4	0,07	20,5	0,07	8,5
8	12	0,08	8,8	0,04	64	0,04	26
		0,1	7,1	0,05	47,5	0,05	20
		0,15	5,6	0,07	32,5	0,07	14
	10	0,08	10	0,04	70	0,04	26,5
		0,1	8,5	0,05	55	0,05	20,4
		0,15	6	0,07	36,2	0,07	14,3
10	15	0,08	11	0,04	81	0,04	33
		0,1	3,2	0,05	61	0,05	23
		0,15	6,7	0,07	41	0,07	17

1. DECHKO, E. M. et al

2. BETTER LIFE FROM DRILLS

3. RUSSIAN ENGINEERING JOURNAL, Vol. 51, No. 12, 1971, pp. 77-78

4. Comparative tests were performed on drills produced by grinding, milling and longitudinal-helical rolling. The test drills were of 5 and 9.8mm diameter, made from the same melt of R6M3 steel (HRC 63-64) and heat-treated simultaneously. The flutes of drills produced by grinding and milling were formed at feeds of 750-900mm/min and 140-160mm/min respectively.

The 5 and 9.8mm diameter drills were tested at cutting speeds of 35.8 and 35.7m/min and feeds of 0.13 and 0.20mm/rev respectively. Cutting forces were measured at cutting speeds of 28.3 and 16.2m/min. The drills were clamped in the chuck; the land eccentricity did not exceed 0.05mm.

The tests showed that, all other things being equal, ground 5mm diameter drills have 100% greater life than milled drills, and 80% greater life than rolled drills (Table 1). The advantages of ground drills, as regards life, are even more marked for 9.8mm diameter drills. It will be seen from these data that ground drills also have greater torsional stiffness.

Because the enhanced life of ground drills cannot be attributed merely to their greater torsional stiffness, the effect of the surface state of 9.8mm-diameter drills on their life was studied by determining the micro-hardness, the 2nd-order stresses, the shear angle and friction coefficient on the drill rake-face and the cutting force.

The micro-hardness of the drill surface layers was measured on the helical flute, the land and the drill core using a PMT-3 instrument with 100gf load, taking specimens polished with aluminum oxide (Table 2).

It will be seen that, for all the drills, maximum micro-hardness was observed on the core, and minimum on the lands. Ground drills are distinguished in that they have not only maximum micro-hardness values, but also minimum fluctuations in various sections.

The 2nd-order stress (micro-deformations $\Delta a/a$ and mosaic block dispersion D_{NKL}) were determined in an X-ray structural analysis unit. The $\Delta a/a$ and D_{HKL} values given in Table 3, which were obtained by the approximation method, show that the micro-stresses and mosaic block dimensions are greater in rolled drills than in ground drills.

4. (Continued)

The shear angles and friction coefficients on the drill rake faces were determined on the roots of chips produced in a special device. Steel 45 was drilled with a feed of 0.17mm/rev and a cutting speed of 8.2m/min, i.e., in conditions of minimum built-up edge formation. The friction coefficient was calculated from the formula

$$f = 1 - \tan(\beta - \gamma)$$

where β is the shear angle and γ the actual rake. Details of shear angles and rakes in a direction normal to the cutting edge are given in Table 4.

The tests showed that, for 9.8mm drills, the axial cutting force is 20-40% higher with rolled drills than with milled and ground drills respectively. For 5mm drills, the production method did not significantly affect the cutting force (see Table 1). In 9.8mm drills produced by longitudinal-helical rolling, the cutting force, tool life and friction coefficient between the chip and the drill rake-face were affected, in the authors' opinion, by the presence of up to 0.16mm concavity in the region of the chisel edge. General results for 9.8mm diameter drills are given in the illustration.

Table 1

Drill diameter (mm)	Drill flute forming method	Mean parameter values for tested drills								Life T (min)	Eccentricity of chisel edge (mm)	Eccentricity of core (mm)	Specific torsional stiffness δ_β (kgfmm/°)	Axial cutting force P_o (kgf)	Torque M (kgfcm)
		Core thickness (mm)	Thickening of core (mm) per 25mm of flute length	Land width (mm)	Tooth diameter (mm)	Tooth width (mm)	Lip clearance angle $\alpha°$	Chisel edge angle $\psi°$	Axial eccentricity of cutting edges (mm)						
5	Grinding	1,01	0,46	0,42	4,75	3,29	13,7	45,7	0,05	66,3	0,04	0,04	112	82,2	11,8
	Milling	1,05	0,42	0,44	4,37	3,22	13,7	46,2	0,04	37,8	0,03	0,05	88,2	82,2	11,6
5	Grinding	1,49	0,12	0,74	4,82	3,49	12	51,8	0,03	40,6	0,03	0,04	88,9	126	12,9
	Rolling	1,42	0,06	0,70	4,33	3,12	11,2	47,2	0,03	22,9	0,02	0,04	69,7	121,4	13,1
9	Grinding	1,75	0,47	0,96	9,63	6,63	10,3	52	0,04	44,6	0,03	0,03	150,3	233	68,4
	Milling	1,72	0,46	1,08	9,02	6,19	9,5	51,8	0,04	12,9	0,055	0,045	114,1	257	70,4
	Rolling	1,67	0,43	0,93	9,01	6,25	11	49,6	0,05	6,8	0,015	0,02	87,3	324	70

Table 2

Drill production method	Micro-hardness (kgf/mm²)		
	flute	land	core
Grinding	883	856	884
Milling	846	743	900
Rolling	704–941	630	911

Table 3

Drill production method	Drill land		Drill flute	
	$\Delta a/a \cdot 10^3$	D_{HKL} (Å°)	$\Delta a/a \cdot 10^3$	D_{HKL} (Å°)
Grinding	1,42	370	0,19	240
Milling	2,12	400	0,68	250
Rolling	4,17	1070	1,57	275

Table 4

Drill production method	Shear angle $\beta°$	Actual rake $\gamma°$	Friction coefficient f
Grinding	37	26	0,81
Milling	27	36	1,16
Rolling	21	40	1,34

1. GARINA, T. I. and SINEL'SHCHIKOV, A. K.

2. CUTTING RATES FOR DRILLING SMALL HOLES

3. MACHINES AND TOOLING, Vol. 42, No. 2, 1971, pp. 46-48

4. Care must be taken to satisfy a number of requirements in drilling small holes. For example, the spindle eccentricity and the perpendicularity error of the spindle axis relative to the table working face must not exceed 0.005 mm. When large numbers of similar parts are machined they must be clamped in quick-release fixtures. For reliable operation of small-diameter drills the eccentricity of the cutting edges must be minimal.

On the basis of test results it is possible to recommend the following minimum surface finish to prevent tool fracture during in-feed:

Drill diameter d (mm)	up to 0.5	0.5-0.7	0.7-1
Blank surface finish class	6-7	5-6	4-5

In addition, test results show that a core thickness of $K = (0.22\text{-}0.24)d$, a point angle of $2\phi = 118\text{-}120°$ and a clearance angle of $\alpha = 28\text{-}30°$ are optimum for machining plain-carbon constructional steels.

Maximum tool life is obtained if drills of the given geometry are used with the recommended (Table 1) cutting rates (see Fig. 1).

With increasing drilling depth, the chip-formation and chip-removal conditions are greatly impaired. Furthermore, the amount of cutting fluid reaching the cutting zone is also greatly reduced; this leads to a drop in drill life (Fig. 2a).

As the overhang increases to 10d, drill life remains substantially unchanged, but above this figure life drops sharply (Fig. 2b), because of loss of stability.

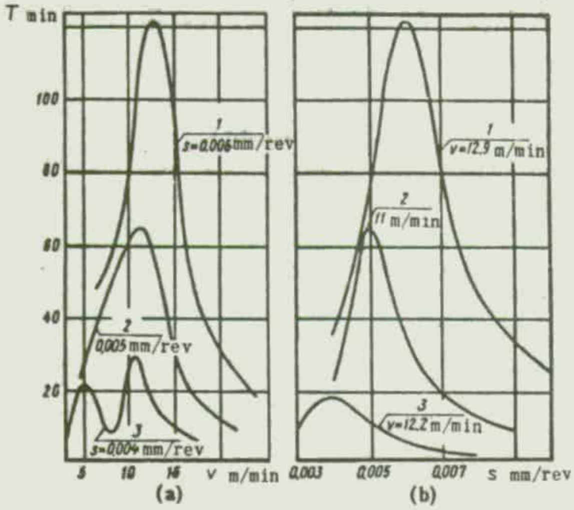


Fig. 1. *a – life plotted against cutting rate;*
b – against feed rate.
Curves: 1 – for drills with d=1mm;
2 – d=0.7mm;
3 – d=0.5mm.

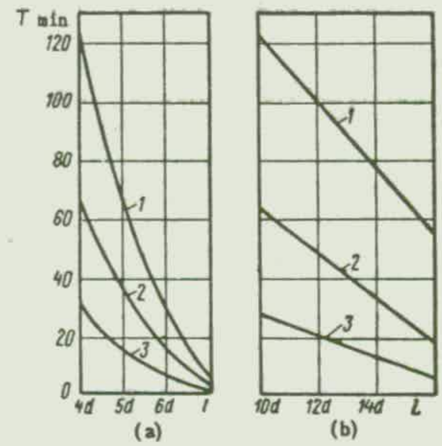


Fig. 2. *a – life plotted against drilling depth;*
b – against drill overhang.
Curves: 1 – d=1mm;
v=12.9m/min, s=0.006mm/rev;
2 – d=0.7mm, v=11m/min, s=0.005mm/rev;
3 – d=0.5mm, v=10.7m/min, s=0.004mm/rev.

Parameters	First batch of drills	Second batch of drills
Eccentricity of chisel edge (mm)	0–0.015	0.02–0.07
Misalignment of core (mm)	0–0.01	0.01–0.06
Land width (mm)	0.21–0.25	0.26–0.37
Lip clearance angle	30–32°	20–26°
Point angle	120–122°	110–125°

Table 1

1. VINOGRADOV, A. A., and ANOSOV, YU. L.

2. DRILLING HIGH MANGANESE STEELS WITH CEMENTED CARBIDE DRILLS

3. MACHINES AND TOOLING, Vol. 42, No. 4, 1971, pgs. 43-45

4. In these investigations, productive drilling conditions were determined for 45G17Yu3, 45G17Yu3Kh and similar, high-manganese, steels. Both normal drills and drills which had internal ducts for delivery of cutting fluid and which were fitted with VK8 cemented-carbide tips were used.

In accordance with known practice, the drill cutting-section was asymmetrically shaped, as a result of which the drill did not vibrate and the chips were separated across the width. The parameters $\Delta\phi$ and ℓ (Fig. 1) were determined whilst machining steel 45G17Yu3Kh. The angle $\Delta\phi$ on a section of the cutting edge of one blade adjacent to the transverse edge was selected, according to the drill diameter D.

D mm	10-15	15-20	20-25
$\Delta\phi$	10°	8°	6°

Figure 2 shows the dependence of drill life T on cutting speed when drilling through-holes (s = 0.06mm/rev) with standard drills, 20mm diameter (curve 1), and blind holes 2D deep (curve 2). Comparing the curves of T = f(v) for internally-cooled drills (19mm diameter) with the same feedrate (curve 3), it is seen that when v = 30 to 40m/min the life of all the drills is about the same.

When the speed is further increased, internally-cooled drills last longer; here, the nature of the T = f(v) relationship remains unaltered. It was also found that when drills with internal ducts were cooled by flooding them with cutting fluid their life was 25% shorter when $v \leq 40$m/min, and 43% shorter when $v > 50$m/min, than when they were internally cooled.

The dashed curve in Fig. 2 corresponds to known data, which was obtained whilst drilling steel 45G17Yu3 with internal delivery of the cutting fluid at a pressure of 25atm. Bearing in mind that steel 45G17Yu3Kh is more difficult to drill than steel 45G17Yu3, the results obtained with internal delivery of the cutting fluid, at a pressure of 25atm (and also at 0.3 to 0.4atm - the latter applied to drills via an asymmetrical duct), and when the cutting fluid is flood-delivered can be considered approximately the same.

The dependence of drill life on diameter T = f(D) was determined whilst drilling blind holes (v = 37m/min, s = 0.06mm/rev) with conventional drills of 12, 14, 20 and 25mm diameter. The dependences of the life of standard drills on the feedrate (Fig. 3) when drilling blind holes (curve 1), and through-holes

4. (Continued)

(curve 2), were determined with a 20mm-diameter drill at v = 37m/min. When drilling through holes at feedrates of up to 0.084mm/rev, drill life is approximately halved; at high feedrates the drill disintegrates at the cutting edges.

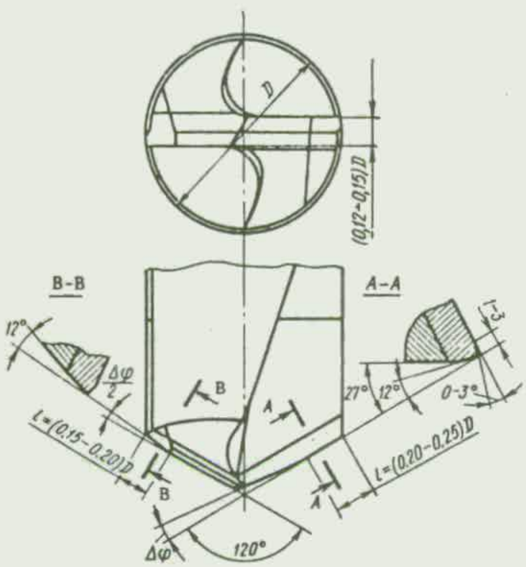


Fig. 1

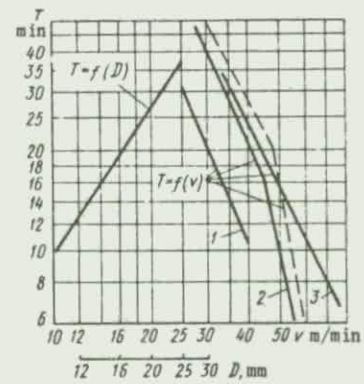


Fig. 2

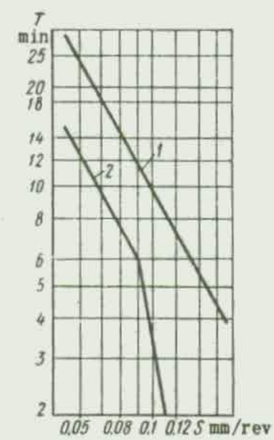


Fig. 3

1. LYUBIMOV, V. E., et al

2. CEMENTED-CARBIDE DRILLS WITH HIGH-STRENGTH ALLOY CORES

3. MACHINES AND TOOLING, Vol. 42, No. 9, 1971, pp. 54-55

4. A drill was designed (Fig. 1) with a cemented-carbide point, the cutting teeth of which have different mechanical properties in different sections. The drill has a d = (0.3-0.4)D core made of coarse-grain high-cobalt high-strength alloy of grade VK15 or VK20, and a periphery of grade VK6 or VK8 low-cobalt alloy. These crowns can be produced by pressing, machining plasticized cylindrical blanks or diffusion welding of the core and periphery .

To permit pressing, a special adjustable die (Fig. 2) was built, consisting of two die-blocks: guide block 1 and forming block 2. The die-blocks are pressed in rings 3 and 4 mounted on base 5 and clamped with bayonet nut 6. Punch 7 moves in the guide die-block, which has the same cross-sectional profile as the drill crown. The guide block is made with straight grooves, which greatly simplifies production and fitting with the punch. To permit crowns having the same profile but different helical groove incline angles to be pressed, the forming block is made interchangeable.

Drilling tests on steel 45 were performed with drills of this type having D = 23 mm, a core of d = 0.4D = 9.2 mm diameter of high-cobalt alloy and a periphery of VK8 alloy. The test results showed that these drills have the same life as solid drills of VK8 alloy. In both cases the limiting factor is the wear of the peripheral lip sections.

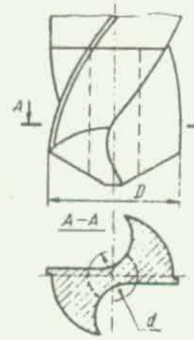


Fig. 1

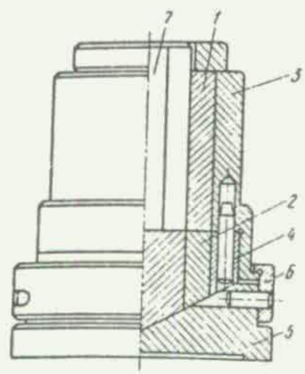


Fig. 2

1. SPZIG, VON J. SIEGFRIED

2. BOHRER GENAU UND SCHNELL SCHLEIFEN (Grinding Drills Accurately and Quickly)

3. WERKSTATT & BETRIEB, 1971, Vol. 104, No. 4, pp. 235-236

4. Points of twist drills tend to be eccentric with respect to the drill centerline due to grinding one cutting edge first, then remounting the drill and grinding the other edge.

   Twist drills are ground with a maximum error of 0.02 mm by successively grinding both cutting edges without intermittent removal of the bit. Instead, the fixture holding the drill is rotated 180 degrees and the second edge is ground by the same wheel. The grinding wheel is worn more evenly, and drill life is improved.

1. SPUR, G. AND PROSSKOWITZ, A.

2. UNTERSUCHUNGEN AN MEHRFASEN-STUFENBOHRERN BEIM BOHREN VON VERGÜTUNGSSTAHL (Investigation of Drilling on Tempered Steel with Step Drills)

3. ZEITSCHRIFT FÜR WIRTSCHAFTLICHE FERTIGUNG, Vol. 66, No. 10, pp. 477-480, 1971

4. Special drill geometries are being used to a greater extent in industry. Step drills or multi-face drills are so designed that various chip formation are formed simultaneously or one after another.

   A significant accuracy can be obtained by the utilization of multi-faced step drills. In these drills, each step diameter contains its own guide face and they have a long life and are able to be reground accurately after it has completely worn off. In order to achieve economical usage, the determination of the optional drilling conditions and the practical operation information are required.

   The effect of wear on the drilling length (or drilling time) of both work materials is shown in Fig. 1. Two work materials, Ck45 (BHN195) and 42CrMo4 (BHN309), were drilled by step drills, HSS S6-5-2, having a diameter range from 18 mm to 26 mm. The feed rate was 0.2 mm and the drilling speed was selected at 22.2 m/min.

   The drill life relationship with the drilling speed, when drilling Ck45 for four different feed rates is indicated in Fig. 2.

   Similar investigation with work material 42CrMo4 shows its result in Fig. 3.

   The progress of thrust and torque by the step drill demonstrates a unique feature, which can be seen in Fig. 4.

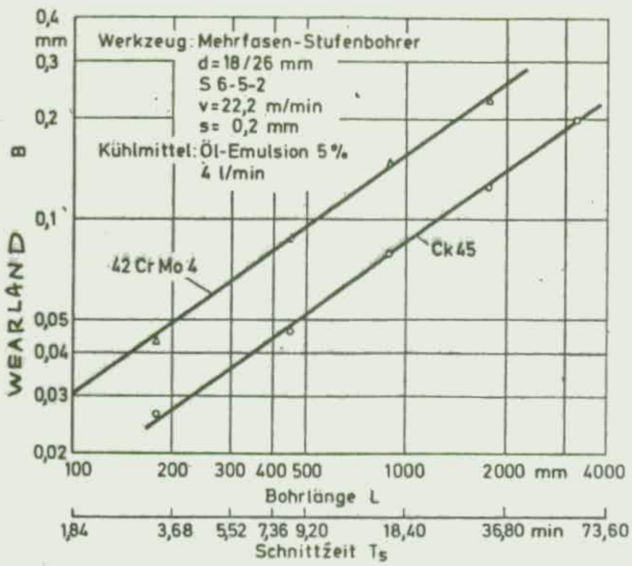


Fig. 1

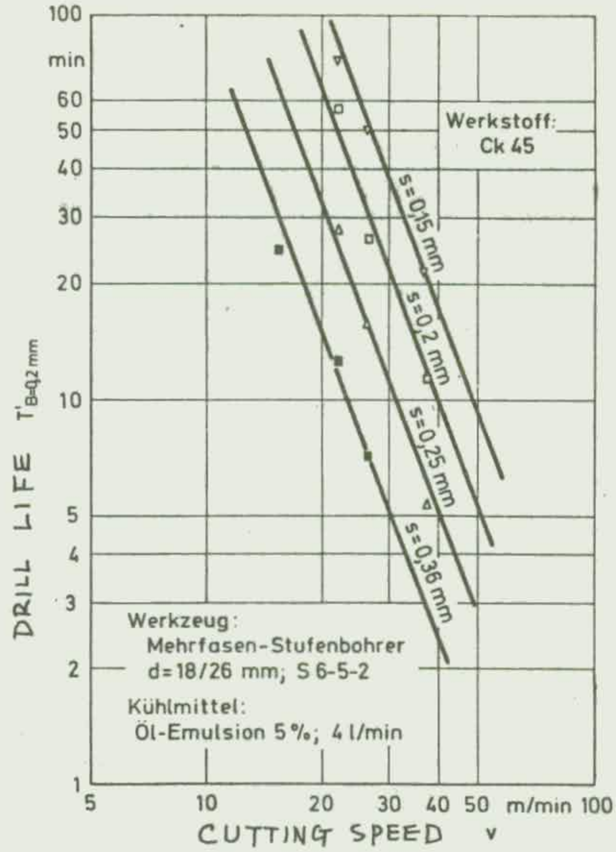


Fig. 2

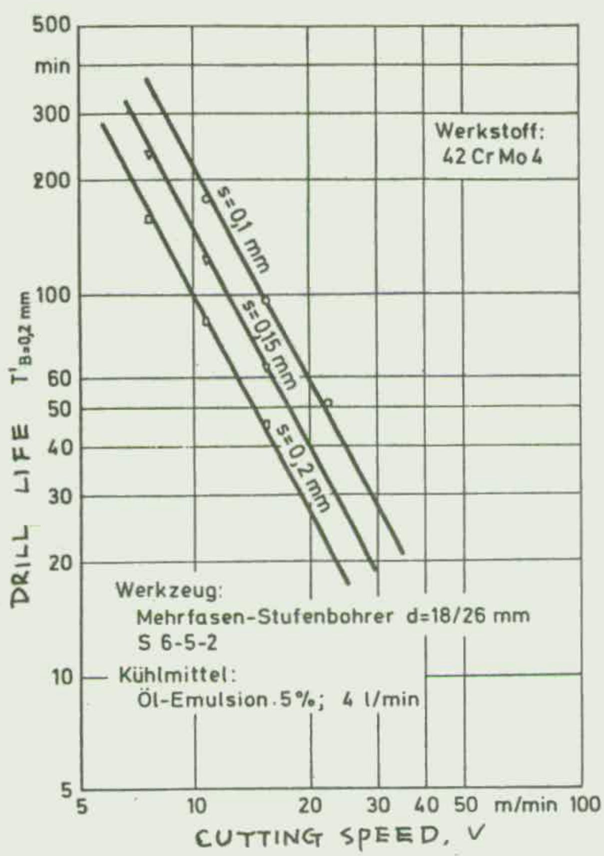


Fig. 3

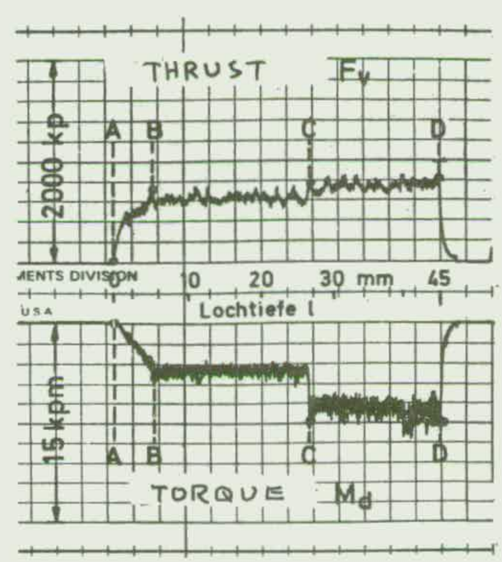


Fig. 4

1. SOLAJA, V., and STANIĆ, J.

2. SELECTED RESULTS FROM A PROJECT ON DRILLING

3. ANNALS OF THE CIRP, Vol. 21/1, 1972, pgs. 33-34

4. The prediction of tool-life as a time function may be considered as an important input in devising the optimum machining parameters under conditions of mechanized and automated production. As the tool wear as a criterion is controlled by a number of influential factors, which in their integral effect may be considered to be stochastic in nature, and has an acceptable level of reliability, it is possible to develop an adequate mathematical model.

The progressive loss of cutting capability of the drill is due to (a) the wear of working elements (two edges, chisel edge, corner and margin) and (b) the chipping of edges, as well as the complete breakdown of the drill. The diagrams in Fig. 1 show the nature of distributions $f(T)$, as well as the relevant reliability functions $R(T)$ and the speed of tool failure $\lambda(T) = f(T)/R(T)$. When regular drilling conditions are ensured, such as those in the case (a), a normal distribution of tool-life for a predetermined level of tool-wear may be expected.

With B as the chosen wear parameter and $T = f(B)$ describing the group of experimental values in tool-life testing, the validity of the equations

$$f'(B_T)(B_T + C_1) - f(B_T) = 0, \qquad (1a)$$

$$f'(B_e)(B_e + C_2) - f(B_e) = 0, \qquad (1b)$$

has been proved. They define the wear parameter B_T when a maximum working life (including all regrinds) of a drill is required, and B_e for the case of minimum production costs.

An analytical approach to the optimization of drilling suggested by equations (1a) and (1b) is, however, not feasible unless the time functions $B = f(T)$ are known. In an attempt to find an acceptable solution, regression curves describing the progress of wear with time, as hypotheses that appear to be the most probable, may be devised in the form

$$B = a\ T^b, \qquad (2)$$

$$B = a\ b^T, \qquad (3)$$

$$B = c + a\ t^b, \qquad (4)$$

An experimental wear curve obtained when drilling cast iron (to the Yugoslav specification SL.26) with a DMo5 high-speed steel drill, diameter D = 13 mm, cutting speed v = 33.5 m/min, feed s = 0.29 mm/rev., no cutting fluid, is reproduced in

4. (Continued)

Fig. 2 (curve 1), and the margin wear B_m, as shown in the accompanying illustration of the wear zone, is chosen as the decisive wear parameter. The curves 2, 3 and 4 describe the experimental wear curve according to equations (2), (3) and (4), with the coefficients and exponents obtained as mean square values from individual test results. Without further detail, the predictions of B_m as functions of cutting time T in the form of (2)-(4) are inserted in Fig. 2 as well.

The main points of the report may be summarized as follows: (i) the wear of twist drills in the prevailing part of the second and at the start of the third segment of the wear curves, may be described by a mathematical model; (ii) the influence of initial wear, denoted by c in (4), requires special care in such instances as predicting tool-life from the intensity of wear I only, i.e. I = dB/dT; (iii) the exponent b in (4) does not seem to depend greatly on the cutting speed; (iv) the feed s and the diameter of the drill D appear to exert a notable influence upon the constants in (4).

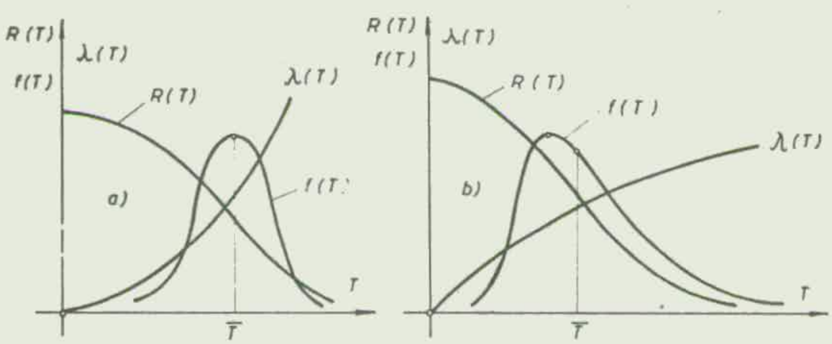


Fig. 1.

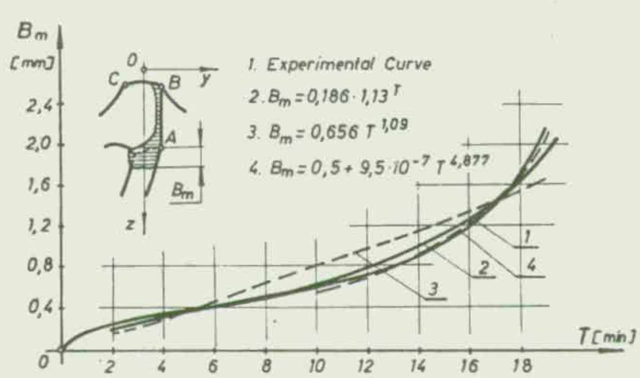


Fig. 2.

1. LAW, S. S., DeVRIES, M. F., and WU, S. M.

2. ANALYSIS OF DRILL STRESS BY THREE-DIMENSIONAL PHOTOELASTICITY

3. TRANSACTIONS OF THE ASME-JOURNAL OF ENGINEERING FOR INDUSTRY, Series B, November, 1972, pp. 965-970

4. An exploratory drill point stress analysis was obtained experimentally using a three-dimensional photoelastic technique. A drill model was stress-frozen under simulated drilling conditions and seven segments were sliced perpendicular to and along the cutting edge for subsequent photoelastic analysis. Isochromatic fringe patterns from slices close to the drill periphery suggest an action analogous to orthogonal cutting. Generally, stresses become more compressive as the cutting edge or the outer corner is approached. A maximum shear stress was found to exist along the cutting edge at a point about three-fourths of the distance from the chisel edge and was noted to be similar to a previously determined cutting edge temperature distribution.

Measurements of the drill model indicated that the model and the actual drill were essentially the same size. An aluminum block with attached chips was made for simulating the drilling action. The same three-in-dia drill employed in making the drill mold was used to drill the aluminum block. The drill was slowly rotated until suitable chips were formed.

The cutting edges of the drill model pressed against the chips and workpiece as if cutting. An axial thrust was applied to the model by an overhanging beam, a ½-in-dia steel ball, and a 1.5-in-dia disk to achieve a centrally applied and self adjusting load. The torque was applied by attaching Nylon strings to a rod passing through the drill base. The thrust and torque were applied to the drill through dead weights. The drill model was subjected to the stress-freezing cycle in which the loads were applied for 8 hours at 245 F.

1. FUJII, S., DeVRIES, M. F., and WU, S. M.

2. ANALYSIS & DESIGN OF A DRILL GRINDER AND EVALUATION OF GRINDING PARAMETERS

3. TRANSACTIONS OF THE ASME - JOURNAL OF ENGINEERING FOR INDUSTRY, Series B, November, 1972, pp. 1157-1163

4. A prototype drill grinder was designed and built based on a computer aided drill point geometry analysis. The new grinder controls all essential drill point grinding parameters. The new grinder was evaluated by grinding drills, measuring their point geometry parameters, and comparing these measurements with their expected values. The effects of five parameters, consisting of three grinding and two cutting condition parameters, on the drill thrust and torque are determined by an experiment using a two-level factorial design. The new grinder was built upon the framework of an existing Sellers Type 1G drill grinder.

   The proper orientation of the grinding cone and drill coordinate system necessary to generate the drill point is shown in Fig. 1(c). To accomplish the required rotations and translations to have the coordinate system and the grinding cone located in proper perspective, the first step is to rotate the drill an angle ω around line A as shown in Fig. 1(b). The xy-coordinate system must then be translated the distances x_V and y_V in the x and y directions as shown in Fig. 1(c). Thus, if the rotation angles μ and ω, and the distances x_V, y_V, and z_V are properly determined, the cone vertex O will lie on the extension of the left side cutting edge and the desired point configuration will be obtained.

   The grinding wheel surface is assumed to be perpendicular to plane P and to contain line B in Fig. 1(a). If line B is rotated around the cone axis, a cone with vertex O and cone semiangle θ will be generated. Because the wheel surface is perpendicular to plane P, the wheel surface will be tangent to the cone generated by line B, a portion of which is the drill flank surface.

   If the drill in Fig. 1(c) is rotated around the cone axis so that the left side cutting edge is on plane P as shown in Fig. 2, the cutting edge will coincide with line B because the angle between the cutting edge and the cone axis in Fig. 1(c) is the cone semiangle θ.

   The angle μ in Fig. 1(a) is the angle formed by the cone axis and line A; it is the direction angle of the cone axis with respect to the z-axis because the drill axis (i.e. the z-axis) and line A are parallel. The direction cosine n of the cone

4. (Continued)

axis with respect to the z-axis is used to calculate μ. The angle ω is the angle formed by the x-axis and the projection α the cone axis on the xy-plane.

A schematic diagram of the prototype grinder design is shown in Fig. 2. The rotations and translations in this figure accomplish the same purpose as that in Fig. 1; i.e., to obtain the proper drill and grinding cone orientation. The angular rotation of μ is the same except its rotation center is shifted from O to O´, while the rotation of ω is identical. The major difference in designs lie in the introduction of arbitrary design constants affecting the translations needed to get the drill in its proper orientation.

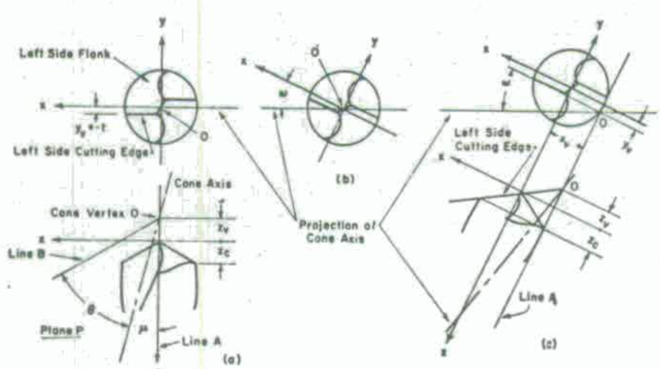


Fig. 1 Procedure for properly orientating the grinding cone and drill

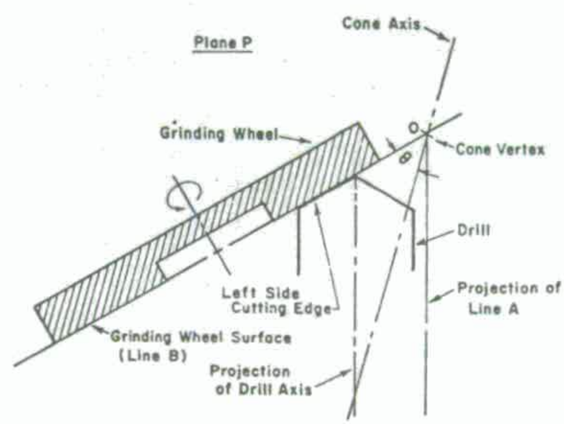


Fig. 2 Proper location of the grinding cone and drill in plane P

1. ARMAREGO, E. J. A., and CHENG, C. Y.

2. DRILLING WITH FLAT RAKE FACE AND CONVENTIONAL TWIST DRILLS - I. THEORETICAL INVESTIGATION

3. INTERNATIONAL JOURNAL OF MACHINE TOOL DESIGN AND RESEARCH, Vol. 12, No. 1, March 1972, pgs. 17-35

4. Abstract - A cutting analysis, based on oblique cutting models, is developed for the drill lips of flat rake face (modified) drills. The analysis predicts reasonable deformation and force distributions along the drill lips. An analysis for conventional drills is also attempted with less success. The concept of geometrical similarity is studied and shown to be useful for prediction of forces in drilling and for the design of twist drills.

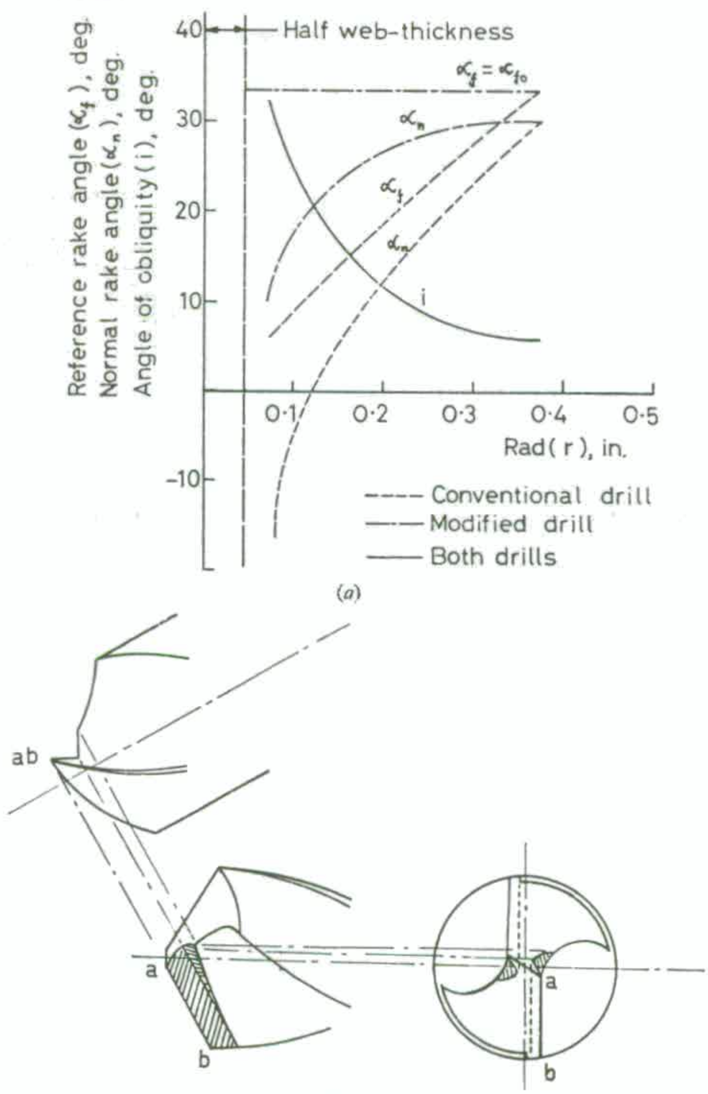


FIG. 2. (a) Variation of drill angles along the drill lips. Drill diameter $D = 0{\cdot}75$ in.; web thickness $2W = 0{\cdot}093$ in.; point angle $2p = 121°\ 5'$; chisel edge angle $\theta = 125°\ 15'$; pitch length $L = 4{\cdot}25$ in. (b) Sketch of flat rake face (modified) drill.

Nomenclature for graphs:

- i angle of obliquity (ℓ = arc sin(sinωsinρ)
- ω web angle
- ρ half point angle
- α_n normal rake angle

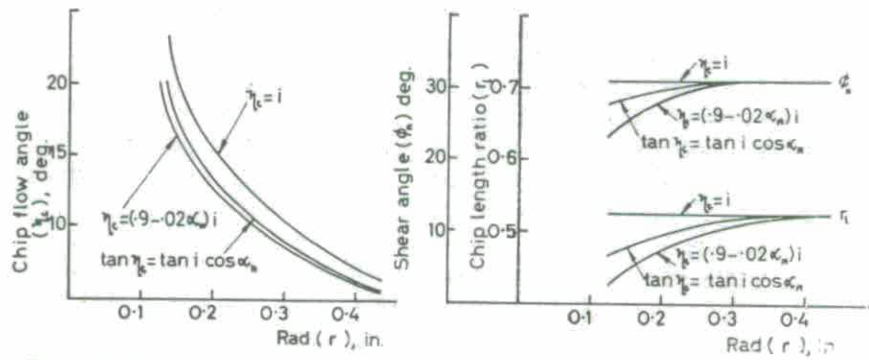


Fig. 5. Predicted variation of chip flow angle, normal shear angle and chip length ratio along the drill lips. Drill diameter $D = 1 \cdot 00$ in.; web thickness $2W = 0 \cdot 120$ in.; point angle $2p = 120°$; chisel edge angle $\theta = 124°$; pitch length $L = 5 \cdot 35$ in.; feed $f = 0 \cdot 005$ in/rev; assumed chip length ratio r_l at $0 \cdot 426$ in. radius $= 0 \cdot 533$.

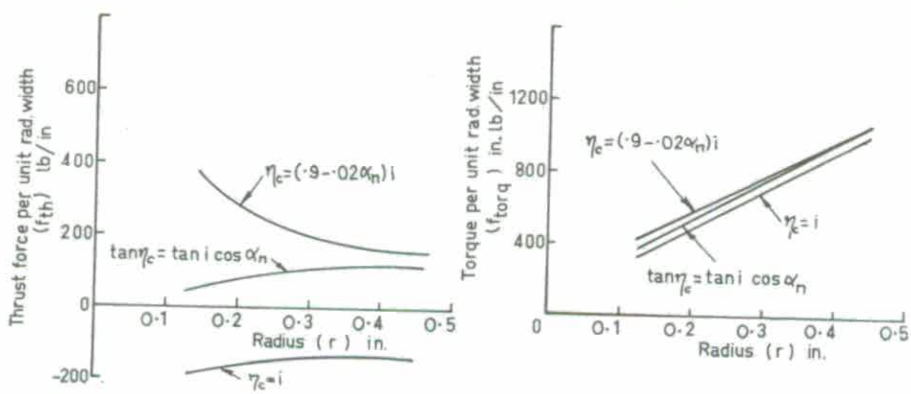


Fig. 6. Predicted variation of thrust force and torque per unit radial width along the drill lips. Inside and outside radii of annular workpiece considered equal to $0 \cdot 092$ in. and $0 \cdot 426$ in. respectively; assumed shear stress $\tau = 40{,}000$ lb/in^2. Other conditions as in Fig. 5.

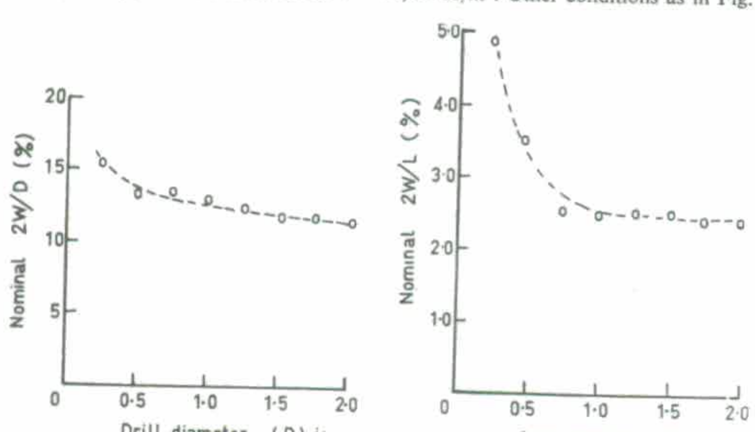


Fig. 9. Variation in nominal web thickness to diameter and web thickness to pitch length ratios for different sized general purpose conventional drills.

1. ARMAREGO, E. J. A. and CHENG, C. Y.

2. DRILLING WITH FLAT RAKE FACE AND CONVENTIONAL TWIST DRILLS - II. EXPERIMENTAL INVESTIGATION

3. INTERNATIONAL JOURNAL OF MACHINE TOOL DESIGN AND RESEARCH, Vol. 12, No. 1, March 1972, pp. 37-54

4. An investigation was performed on a vertical drill fitted with infinitely variable speed control (150-2000 rev/min) and three feeds (0.005, 0.008 and 0.012 in/rev). A strain gauge drilling dynamometer coupled to u.v. recording galvanometers via matched amplifiers was used to measure the thrust force and torque. The dynamometer consisted of a tubular torque element centrally mounted on a horizontal circular disc supported by three half-rings equally spaced about the vertical axis. The rings, for registering the thrust force, were screwed to the dynamometer base plate clamped to the drilling machine table. The dynamometer was centered with respect to the spindle axis by means of a rod fitted to the drill spindle and mating the torque element. The cylindrical workpieces were also centrally located on the tubular torque element. Figure 1 shows the general layout of the equipment and a sketch of the centering rod, torque element and workpieces.

Aluminum alloy (65S-T6) workpieces were used in these experiments. The tests envisaged in this work required solid cylindrical workpieces as well as tubular annuli of varying thickness so that the overall workpiece length was kept short (about 1 in.) to maintain rigidity. Due to this short workpiece length and the fact that cutting speed was not a major variable in this investigation, it was convenient to use the lowest spindle speed for maximum workpiece utilization. However, preliminary force tests were run using a 1 in. diameter conventional drill at ten spindle speeds ranging from 150 to 500 rev/min.

Two sets of H.S.S. drills were used. The first set, selected from an initial batch of as received point-thinned drills, represented partially similar drills since 2W/L was constant while 2W/D varied. These drills, listed in Table 1, could only be used for similarity tests at the drill lips when tubular workpieces or pre-determined radii were machined. The second set was chosen from another larger batch of as received drills without point-thinning. Table 2 gives details of the five drills selected which can be considered completely similar for all intents and purposes. Drills G and H in Table 2 are modified drills. The dimension of the ground flat rake face in Fig. 2 was selected such that X was symmetrical about the drill axis and equal to 1/3 the web thickness.

4. (Continued)

The deformation and the thrust force and torque equations based on the geometrical similarity concept were experimentally verified for conventional and modified drills using statistical techniques.

The expected reduction in thrust force and torque due to drill lip correction and point-relieving when conventional drills are modified by the method described was confirmed and shown to be substantial.

The cutting analysis for the drill lips of modified drills was shown to be qualitatively and quantitatively sound. The thrust and torque on the drill lips can be predicted provided basic oblique cutting parameters are known. Further work incorporating the chisel edge action is desirable.

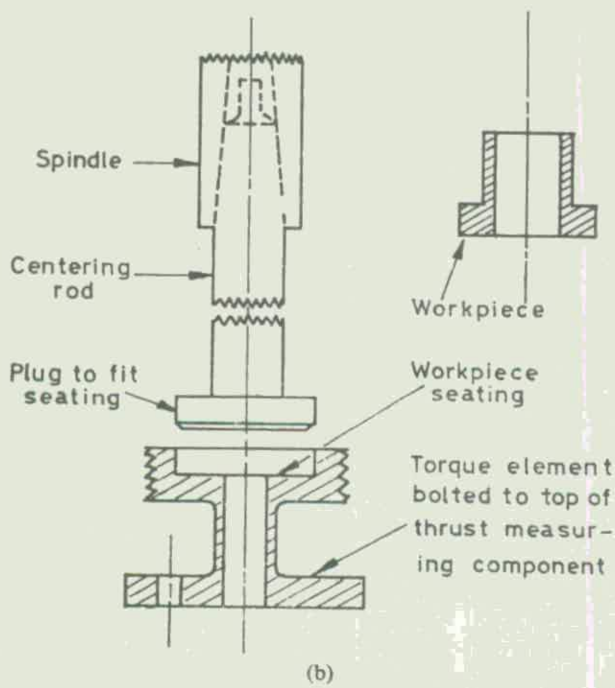


FIG. 1. General layout of equipment and method of centreing dynamometer and drill axis.

TABLE 1. PARTIALLY SIMILAR DRILLS

Drill	Diameter D (in.)	Web thickness 2W (in.)	Pitch length L (in.)	Chisel edge angle $\theta°$	Point angle $2p°$	2W/L %	2W/D %
A	0·75	0·109	4·37	122° 45′	119° 00′	2·5	14·5
B	1·00	0·126	5·05	125° 35′	122° 50′	2·5	12·6
C	1·25	0·150	6·35	125° 55′	120° 00′	2·4	12·0

TABLE 2. COMPLETELY SIMILAR DRILLS

Drill	Diameter D (in.)	Web thickness 2W (in.)	Pitch length L (in.)	Chisel edge angle $\theta°$	Point angle $2p°$	2W/L %	2W/D %
D	0·75	0·093	4·25	125° 15′	121° 05′	2·20	12·4
E	1·00	0·120	5·35	124° 04′	120° 50′	2·22	12·0
F	1·25	0·145	6·35	124° 00′	120° 00′	2·28	11·6
*G	0·75	0·093	4·25	125° 00′	121° 30′	2·20	12·4
*H	1·00	0·120	5·35	124° 10′	120° 20′	2·22	12·0

* Modified flat rake face drills.

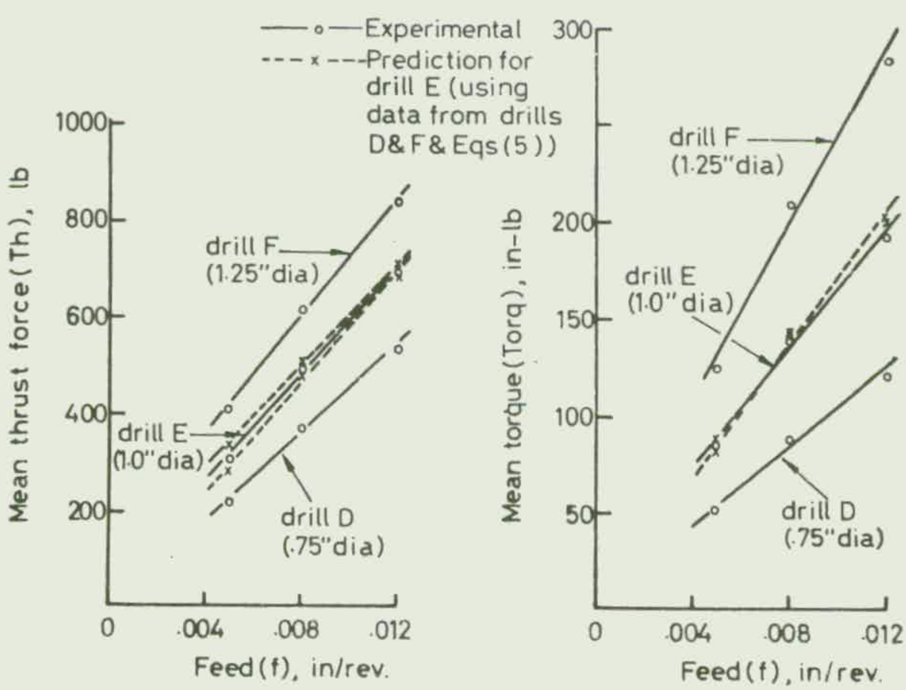


FIG. 3. Comparison of total mean thrust and torque of three similar conventional drills at various feeds. Drills D, E and F as per Table 2; speed: 150 rev/min. Workpiece: 65 S–T6, without pilot holes; cutting dry.

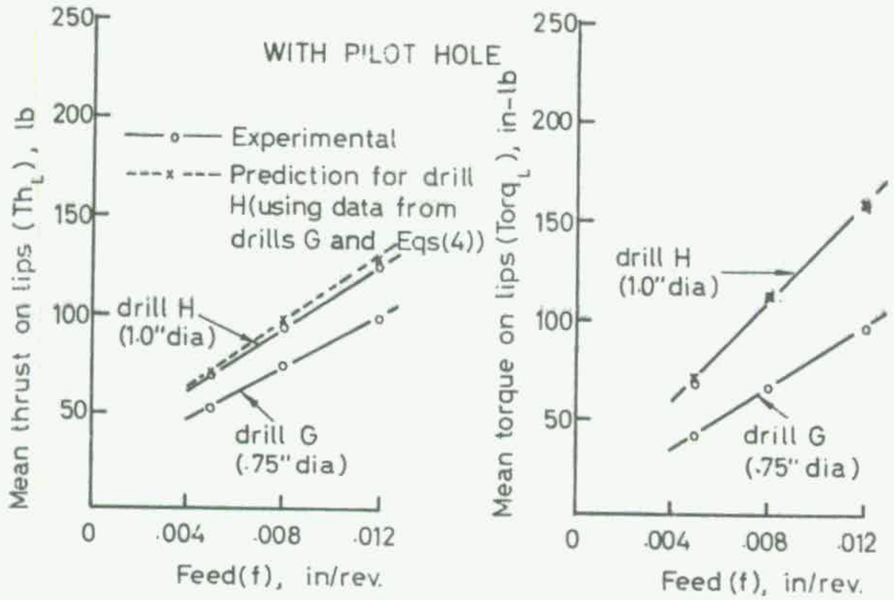


Fig. 4. Comparison of mean thrust and torque on the lips of two similar modified drills at various feeds. Drills G and H as per Table 2; speed: 150 rev/min. Workpiece: 65 S–T6, with pilot holes; cutting dry.

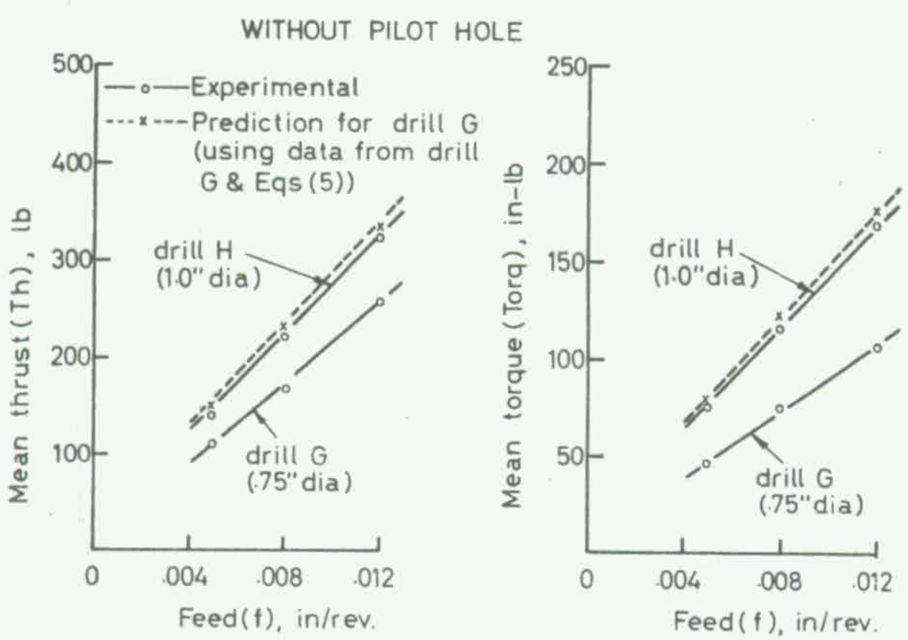


Fig. 5. Comparison of total mean thrust and torque on two similar modified drills at various feeds. Workpiece: 65 S–T6, without pilot holes; other conditions as in Fig. 4.

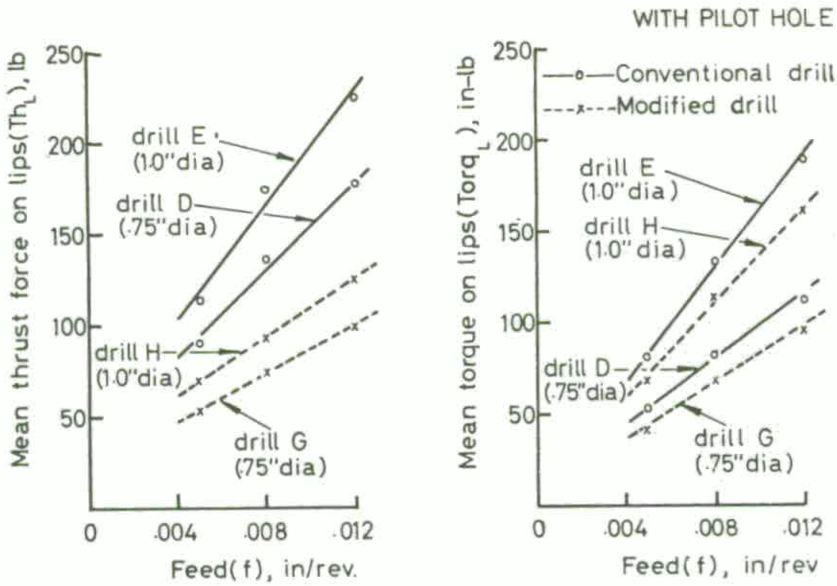


FIG. 6. Comparison of mean thrust and torque on the lips of conventional and modified drills at various feeds. Drills D, E, G and H as per Table 2; speed: 150 rev/min. Workpiece: 65 S–T6, with pilot holes; cutting dry.

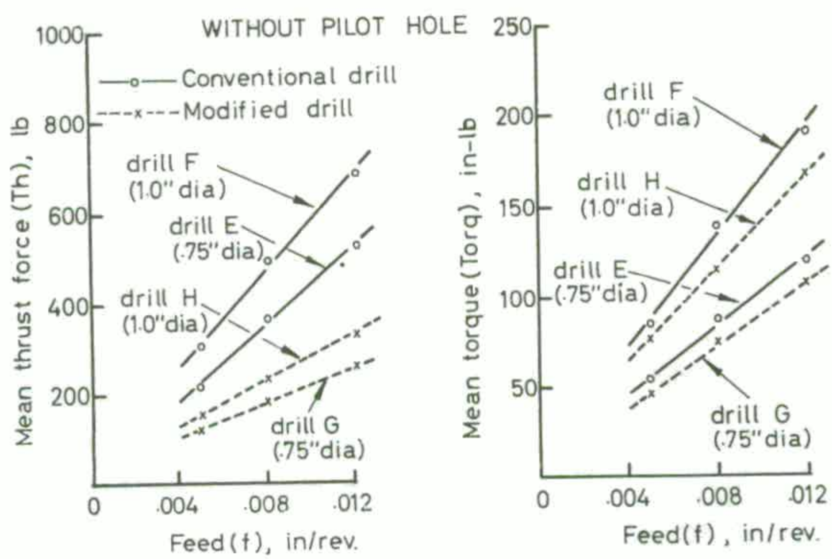


FIG. 7. Comparison of total mean thrust and torque of conventional and modified drills at various feeds. Workpiece: 65 S–T6, without pilot holes, other conditions as in Fig. 6.

TABLE 7(a). DIMENSIONS OF ANNULI TESTED

	Annulus				
	1H	2H	3H	4H	5H
Inside radius (in.)	0·092	0·175	0·259	0·342	0·092
Outside radius (in.)	0·175	0·259	0·342	0·426	0·426

TABLE 7(b). ANALYSES OF VARIANCES OF MEAN r_l AT EACH RADIUS FOR DIFFERENT FEEDS AND ANNULI

	Radius (in.)				
	0·092	0·175	0·259	0·342	0·426
Mean r_l	0·444	0·481	0·519	0·524	0·533
Degrees of freedom	5, 30	5, 30	5, 30	5, 30	5, 30
Variance ratio (F-test)	0·50*	0·36*	0·07*	0·09*	0·16*

* Not significant at 95 per cent confidence level.

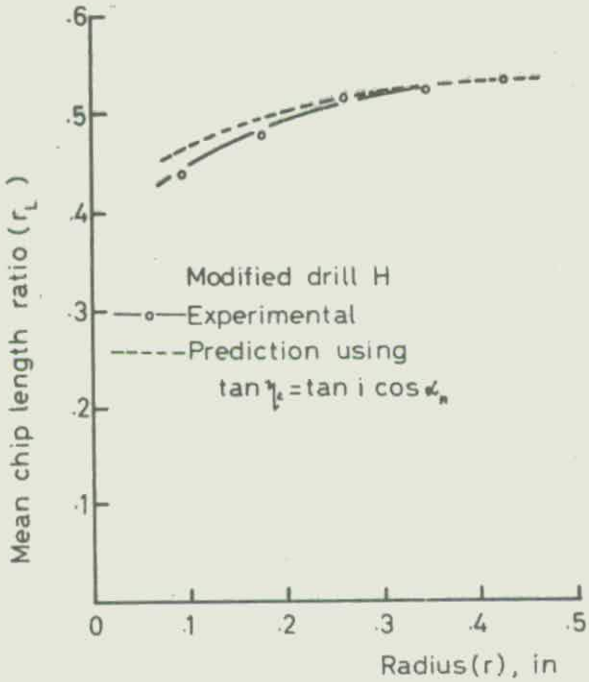


FIG. 9. Comparison of experimental and predicted mean chip length ratios along lips of modified drill (using chip flow rule $\tan \eta_c = \tan i \cos \alpha_n$). Feed: 0·004, 0·008 and 0·012 in/rev; other conditions as per Fig. 8.

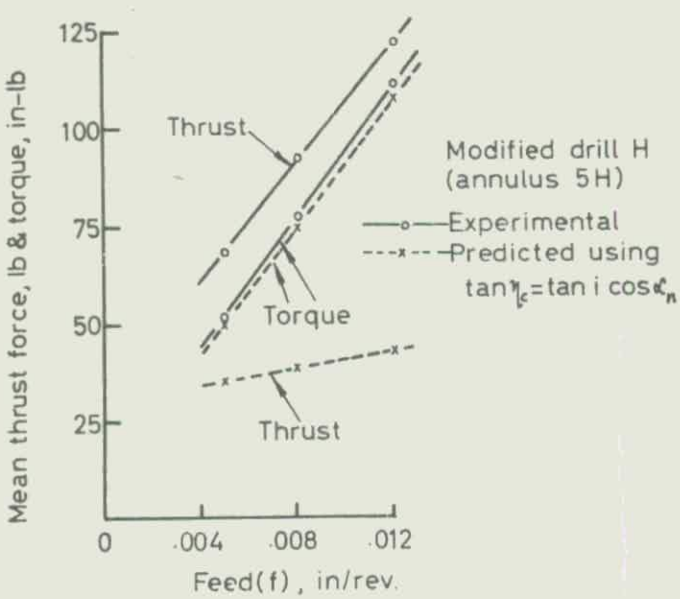


FIG. 10. Comparison of experimental and predicted mean thrust and torque on the drill lips of modified drill (using chip flow rule $\tan \eta_c = \tan i \cos \alpha_n$). Drill H as per Table 2; speed 150 rev/min. Workpiece: 65 S-T6, annulus 5H as per Table 7(a); cutting dry; material shear stress 40×10^3 lb/in^2.

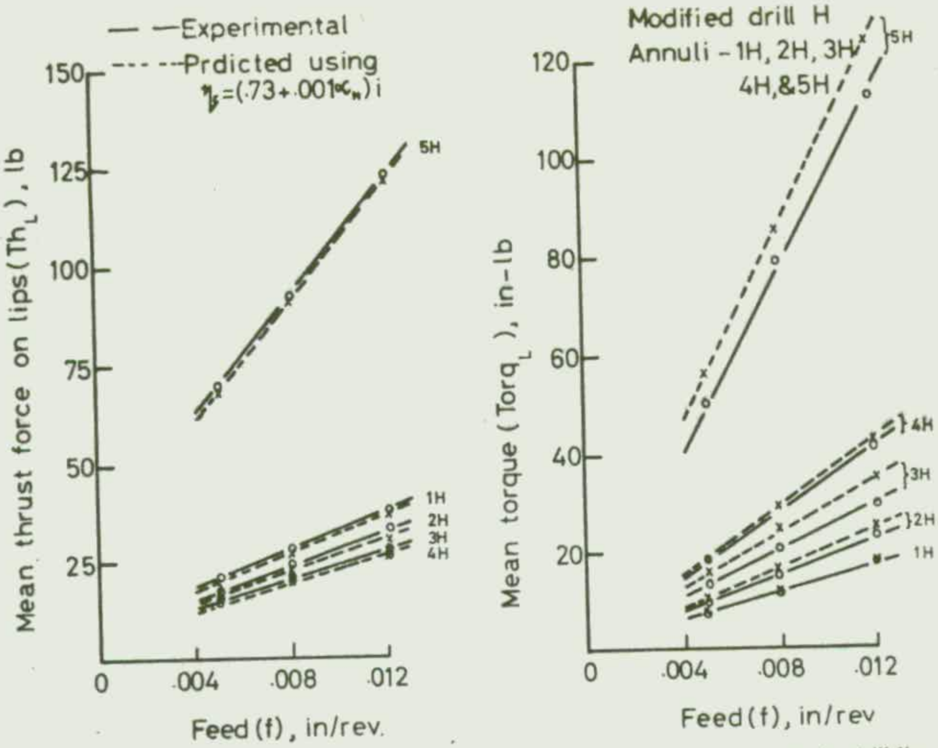


FIG. 11. Comparison of experimental and predicted mean thrust and torque on the drill lips of modified drill (using chip flow rule $\eta_c = (a - b\alpha_n)\,i$). Workpiece: 65 S–T6, annuli 1H to 5H as per Table 7(a), other conditions as per Fig. 10.

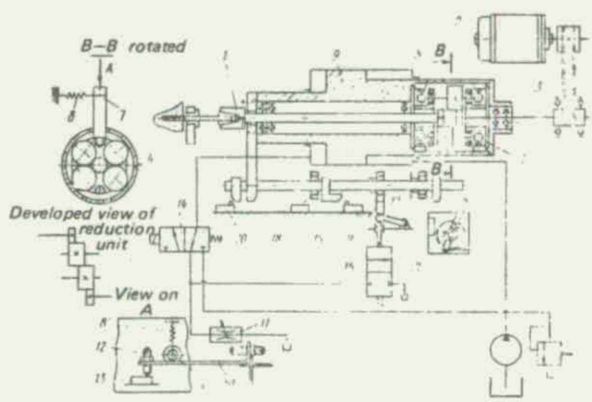
1. TVERSKOI, M. M. and ZAKAMALDIN, V. I.

2. DRILLING SMALL DEEP HOLES WITH TORQUE STABILIZATION

3. MACHINES AND TOOLING, Vol. 43, No. 1, 1972, pp. 15-16

4. A machine for drilling $1.5^{+0.3}$ mm diameter, 24 mm-deep holes has been developed and built. The tool spindle 1 (see illustration) is rotated by an induction-type motor 2, via Vee-belt drive 3 and planetary reduction unit 4, which serves as a dynamometer for measuring the torque on the drill . The load moment is determined from the reactive moment on carrier-arm 5, mounted in bearings 6 and retarded by finger 7 and spring 8 in body 9 of the unit-construction drilling-head spindle barrel.

The required load on the drill is set by varying the pre-tension of spring 8. Finger 7, via lever 10, actuates the plunger of axial throttle 11 controlling the working feed-rate, as a result of which the latter automatically decreases with rising torque on the drill. Given a low stiffness in spring 8, and a large transmission ratio for lever 10, the torque remains practically constant during drilling, because the amount of static irregularity is then small.



Diagrammatic arrangement of machine.

1. KIRILENKO, A. L.

2. IMPORTANCE OF FLUTE HELIX-ANGLE OF TWIST DRILLS

3. MACHINES AND TOOLING, Vol. 43, No. 1, 1972, pp. 48-51

4. To increase the strength and life of a twist drill, the stiffness characteristics must be known, and the drilling stresses must be studied during drilling. This permits proper drill designs and drilling rates to be selected. Up to now, the helical nature of the drill flutes was not taken into account when investigating drill stiffness and strength. Recently, however, experiments and theoretical investigations have shown that the incline of the drill flutes has a significant effect on drill strength and axial and torsional stiffness. The Author proposes a number of formulae for calculating normal and shear stresses, which occur in the drill cross-section due to the helical arrangement of the flutes, and the axial and torsional deformation of the drill, all with respect to torque and axial forces.

1. GARINA, T. I. and SINEL'SHCHIKOV, A. K.

2. EFFECT OF OVERHANG ON THE OPERATION OF SMALL DRILLS

3. MACHINES AND TOOLING, Vol. 43, No. 1, 1972, pgs. 51-53

4. Research conducted showed that if the overhang of small drills (up to 1mm diameter) is correctly selected, drill life and drilling rates can be greatly improved. At present, the same cutting rates are used with both long and short drills, and consequently there is premature failure of long drills because of their lower dynamic stiffness and, hence, greater wear rate (Fig. 1 and Table 1).

When small drills with a large L/d ratio are used, the cutting force causes a loss of axial stability, resulting in loss of rectilinear form, which is maintained when drilling with overhangs up to 10d (Fig. 2). The critical force at which there is transition from one form to the other is expressed as

$$P_{cr} = \frac{EI\pi^2}{(\mu L)^2} \;;$$

where μ is the relative length factor (Fig. 3), which depends on

$$B^2 = \frac{KL^4}{16EI},$$

where K is a coefficient which allows for the cross-sectional form.

The mode of transition from one form to another is confirmed by Fig. 3 according to which with $B^2 = 160$ a form with one half-wave (Fig. 2 form I) is replaced by a form with two half-waves (Fig. 2, form II), and with $B^2 = 350$ there is transition from the form with two half-waves (Fig. 2, form II) to a form with one half-wave (Fig. 2, form III).

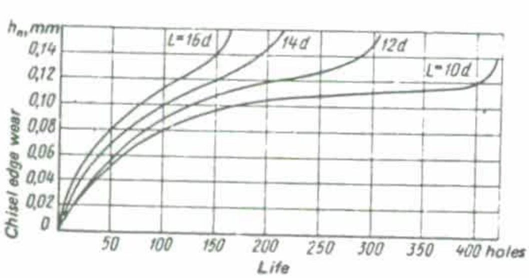


Fig. 1.
Chisel-edge wear h_n plotted against number of holes drilled with various drill overhangs (d = 0,5mm, l = 4d, v = 10,7m/min, s = 0,004mm/ /rev, coolant – turpentine).

Table 1

Effect of drill overhang on life when drilling (carbon) steel 45 (drilling length l = 4d)

Drill diameter (mm)	Speed (rev/min)	Feed (mm/rev)	h_n (mm)	$\frac{L}{d}$	Mean life		Relative life factor
					Number of holes	min	
0,5	6800	0,004	0,12	10 12 14 16	390 250 150 100	30,0 19,3 11,6 7,7	1,0 0,64 0,39 0,26
0,7	5000	0,005	0,14	10 12 14 16	540 400 310 150	65,0 48,0 37,2 18,0	1,0 0,74 0,57 0,30
1,0	4100	0,006	0,20	10 12 14 16	700 550 500 300	122,0 96,0 87,2 53,2	1,0 0,78 0,71 0,43

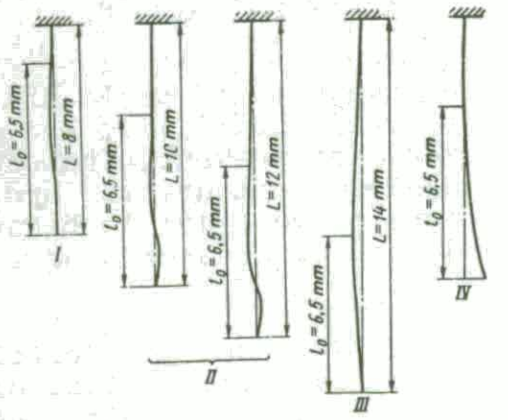


Fig. 2.
Main bending forms of 0,5mm drills with various overhangs when n = 4100rev/min and s = 0,004mm/ /rev.

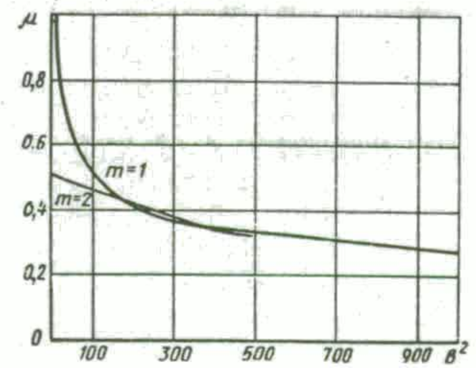


Fig. 3.
Factor μ plotted against B^2; m — number of half-waves.

1. SMAGIN, G. I., et al

2. INCREASED ACCURACY OF SMALL DIAMETER DRILLED HOLES

3. MACHINES & TOOLING, Vol. 43, No. 3, 1972, pp. 41-43

4. An automatic stabilization system was developed for a bench drilling machine, permitting drilling in automatic or manual cycle. The transition from one cycle to the other is made by energizing an electromagnetic clutch in the feed circuit. Tests were performed in which 1.5-3mm diameter holes to Class 1 accuracy were drilled in components of grade MB ductile oxygen-free copper using VK8 cemented carbide drills.

The machine with the stabilization system is shown in Fig. 1. To facilitate the taking-up of blacklash and for greater smoothness of travel, the spindle barrel is mounted on ball slides. Torque is determined by measuring the current in the main drive motor (asynchronous with short-circuited rotor, N = 80W, n = 2800rev/min). The signal is taken from a three-phase transformer, the primary windings of which are connected to each phase of the stator circuit. The feed motor (d.c.) is connected at the amplifier output. It will be seen from Fig. 2 that out-of-phase signal $\Delta\ell$ between nominal and working current ℓ_M of the main motor is the control signal.

With an increasing resistance moment on the drill, the out-of-phase increases, which causes the feed motor current to decrease. Feedback is through the following circuit: workpiece-drill-main motor-probe M_t. If the feed motor in response to the disturbing moment reduces the feed to zero, and the disturbance remains at the critical level (as a result of adhesion of swarf, incorrect grinding of the drill, etc.), the auxiliary elements of the circuit are tripped, and a signal is passed to withdraw the spindle.

To investigate the behaviour of the system, the drilling process was oscillographed with various setting unit current values. The N-700 oscillograph recorded the signal at the input to the electronic amplifier or at the output of the torque probe, and the signal on the feed motor armature.

The following conclusions were drawn from analysis of the oscillograms: 1 - the system reacts to the disturbing moment (to bring M_t back to the normal value) in 0.08s; 2 - when the machine spindle is loaded with a braking moment, the feed motor revolutions drop from the maximum value to zero with an increment in M_t equal to 1kgfmm over the nominal value set on the M_t setting unit; 3 - the system is capable of reacting to disturbing moments rising at rates of up to 30kgfmm/s (with higher rates drill fracture is possible); it should be remembered that when drilling copper, the mean rate of torque rise in the non-regulated zone is 2-5kgfmm/s; 4 - the torque

4. (Continued)

value is maintained constant with an accuracy of ±0.25kgfmm, which is ±10% for 1mm diameter drills and ±3.3% for 2mm diameter drills.

Normal distribution curves (Fig. 3(a)) were obtained for centre co-ordinate deviations of 1.5mm diameter holes, while the deflexion of the hole axis with a drilling depth of 5mm was represented by curves (Fig. 3(b)) identical to the difference module distribution law. Results obtained in the machine with automatic stabilization of M_t were analyzed in the same way (curves 2). In both cases the cutting rates were selected such as to ensure an identical feed rate of s = 40mm/min.

Comparison of the distribution curves shows that when drilling in a machine with automatic regulation of M_t, probability density h_i for smaller deviations x_i of the radius from nominal is greater, and the r.m.s. error value is smaller (see Table 1).

Table 1

Type of machine	Deviation of centre co-ordinate of 1,5mm diameter hole		Deflexion of 1,5mm diameter hole axis		Percentage of scrap
	$\bar{x}$ (µm)	σ (µm)	$\bar{x}$ (µm)	σ (µm)	
With hand feed	−2,19 −2,69 −2,2 −2,715	6,7 6,2 6,3 6,85	6,9 6,068 5,9 6,21	4,38 4 4,1 3,82	8,92 8,11 7,29 11,37
With automatic M_t regulation	0,12	4	2,94	2,3	0,26

Note. $\bar{x}$ – arithmetical mean; σ – r.m.s.

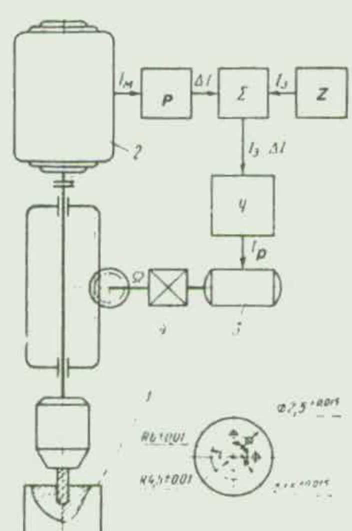


Fig. 2.
Functional diagram of automatic M_t regulation system; P – M_t probe; Σ – summator; Z – M_t setting unit; Y – amplifier; 1 – workpiece; 2 – main drive motor; 3 – feed motor; 4 – reduction gear unit.

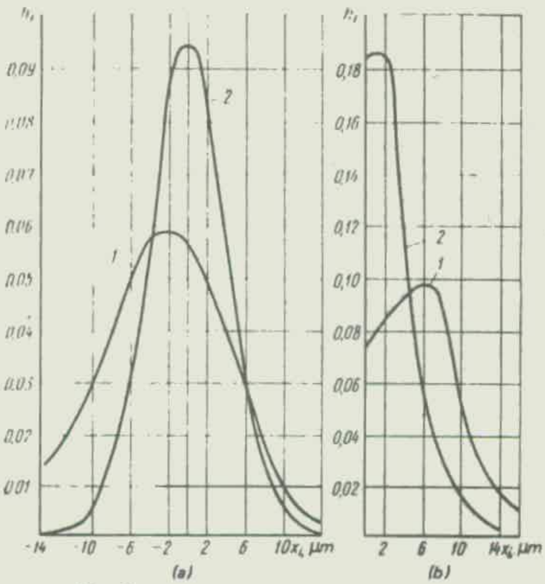


Fig. 3.
1 – distribution curve for parts machined in machine with manual feed;
2 – same for machine with automatic M_t regulation.

1. LISHINSKII, L. YU

2. AUTOMATIC CONTROL SYSTEM FOR MACHINE TOOLS

3. MACHINES & TOOLING, Vol. 43, No. 5, 1972, pp. 25-28

4. The Author discusses an ACS (Automatic Control System) intended for controlling a cutting process, based on information received during the course of the process itself, i.e., systems which use the output parameters of the cutting process and the disturbing influences for feedback (a disturbing influence is understood to be an external activity independent of the control system).

Figure 1 gives a diagram for classifying ACS for metal machining processes on machine tools. In the upper part of the diagram are located automatic boundary control systems (ABCS), automatic regulating systems (ARS) and adaptive control systems (AdCS). ABCS, which are closed systems as regards the cutting process, only produce a demand when the parameter being measured reaches a defined preset level. Such systems ensure displacement to a position with the preset value of the generalized output co-ordinate, but have no control over the trajectory of this displacement. In ABCS the control actions, the parameters, the work structure and its algorithm are, as a rule, unaltered throughout the whole machining process.

ARS systems are also closed. Their control activities are produced by a continuous comparison of the value actually being measured with the preset value. Depending on the nature of the presetting action ARS systems are divided into automatic stabilization systems (ASS), automatic follower systems (AFS), and automatic program controlled systems (APCS). ACS systems in which the control actions, parameters, work structure and its algorithm, are automatically changed in relation to real conditions so as to ensure the extreme, or an approximation to the extreme value of the criterion selected have acquired the name, adaptive systems. Additional characteristics of AdCS are their incomplete determinism (indeterminacy), their logical action, their capacity to make predictions and to learn.

Characteristic of AdCS are their measurement of the factor determining the quality of the work and their alteration of the control activities, parameters, work structure and algorithm in response to its preset value. AdCS are divided into self adjusting systems (SAS), where the control actions or parameters undergo change, and self adapting systems (SAdS), where the work structure or algorithm undergo change. In the use of AdCS the quality of work criteria can be, for example, the time or cost of machining individual items of production, the specific time or cost for removal of the allowance, as

4. (Continued)

well as the accuracy and quality of machining of the workpieces. In their turn, SAS and SAdS are divided into scanning (ScS) and non-scanning ($\overline{ScS}$). The distinguishing characteristic of the former is the variation of the actions, parameters, structure or algorithm of the controlling mechanism as a result of an analysis of the results of test processes on the object to be controlled.

The structure of a control system is also determined by the type of feedback used to control the cutting process. An analysis of possible ACS structures for machine tools has made it possible to establish nine types of feedback which contain information about the condition of the cutting process: i.e., about the cutting force, the torque, cutting power, rotary speed of the spindle, feed, cutting speed, cutting temperature, position of tool or workpiece during the machining process, as well as the static or dynamic characteristics of the MFTW system.

Figure 2 shows the generalized block schematic for ABCS: in this, and in the remainder of the figures, the drive for only one co-ordinate is shown.

The adoption of tool position feedback in ASS to control the amount of static adjustment facilitates an increase in accuracy. In this instance the small displacement drive is the actuating mechanism, whilst the measuring instruments are displacement pick-offs. It should be noted that the design of the transducers in different ASS can be the same even although the measured parameters are different. Fig. 3(a) shows the ASS block diagram. The various methods of introducing feedback are shown by broken lines. With the use of ASS the information α_1 = const.

Fig. 3(a) also shows the correct block diagram for AFS where α_1 is variable.

Figure 3(b) gives a block diagram of an APCS. It contains a computer unit (CU) designed to vary the control actions on the machine tool drive in accordance with an optimal law which is a function of the output parameters of the cutting process. In some instances the CU during the operation of the system varies its parameters in relation to the value of its output co-ordinates or on the state of the process.

Fig. 4 gives a block diagram for a scanning system to control machining processes on machines with NC. The minimizing of the unit cost for removal of the allowance is achieved by an analysis of the results of test measurements of the cutting speed and feed rate relative to some specified scanning procedure.

4. (Continued)

The ACS structures located in the lower part of Fig. 1 are defined by the number of control loops. As previously mentioned ACS can be mono- or poly-parameter systems (respectively MACS and PACS). Analysis has revealed that it is possible to have mutually dependent or independent control loops for rotary speed of spindle, feed rates, position of tool or workpiece, static or dynamic characteristics of the SPID system. Hence the consequence is that four different types of MACS and eleven different types of PACS can be produced depending on the various possible combinations of individual control loops.

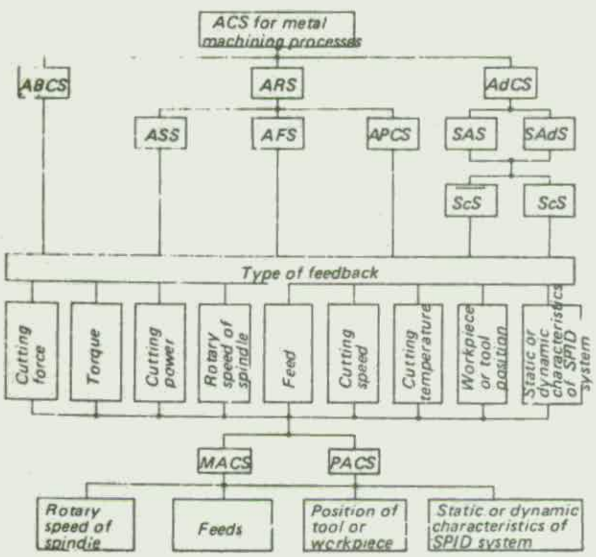


Fig. 1

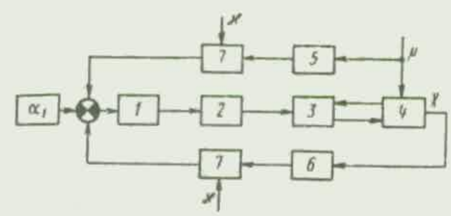


Fig. 2.
Block diagram of ABCS; α_1 – initial information, γ – output co-ordinate of process, χ – setting of limiting (threshold) unit 7, μ – disturbing action;
1 – control;
2 – drive;
3 – machine tool;
4 – cutting process;
5 – compensating links;
6 – feedback circuits.

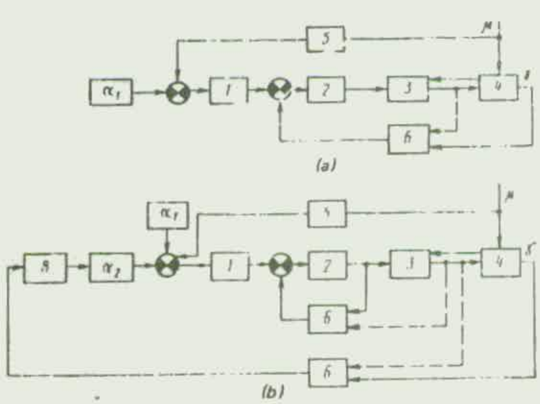


Fig. 3.
ACS block diagram; α_2 – control program for cutting process; 8 – computer. For the remaining legends see Fig. 2.

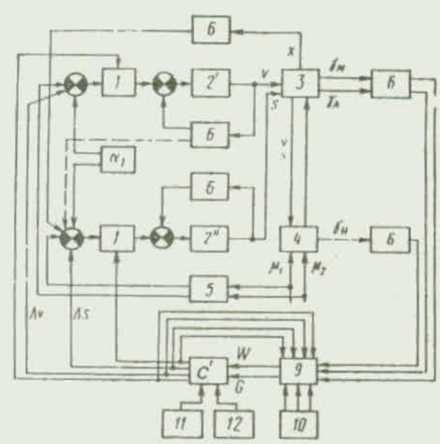


Fig. 4.
Block diagram of scanning control system for machine tools with NC (showing only X co-ordinate); γ_M, γ_A, γ_{θ} – torque, vibration and temperature in cutting zone; W – rate of wear of tool; G – rate of metal removal;
Δv, Δs – change in cutting speed and rate of feed; 2′ and 2″ – main drive and feed drive;
C′ – criteria computer, store, scanner, correction input;
9 – transformation of information;
10 – limiter;
11 – preset level of criteria;
12 – scanning algorithm.
For the other legends see Fig. 2.

1. PRUPIS, L. M., and KOBULADZE, A. N.

2. COOLING SYSTEM FOR DEEP-DRILLING

3. MACHINES AND TOOLING, Vol. 43, No. 8, 1972, pgs. 31-33

4. Figure 1 shows a typical drill cooling system, comprising tank 1, pump 2, safety valve 3, coolant delivery regulation taps 4, filters 5, pressure relay 6 in the pump mains, pressure relays 7 in the coolant delivery line to each drill, coolant delivery couplings 8 to each spindle 10, hoses 9, drills 11 and pipework 12. Particular attention should be paid to the installation of pressure relay 6, which controls the minimum pressure required in the system; the maximum permissible pressure is controlled by a maximum-current relay (based on drive motor loading). Pressure relays 7 control the maximum permissible pressure in the workpiece-drill-spindle-coolant delivery coupling circuit.

If the mains become clogged, the pressure rises to the value upstream of taps 4. If the minimum necessary pressure in the pump delivery line is not reached, or if the maximum permissible pressure in the coolant delivery line to each of the drills is reached, the drill is automatically withdrawn from the hole and a corresponding signal is passed. Tank size, pump delivery, and the sizes of the filters, hoses, taps, couplings, pipework and spindle holes must be selected by calculation.

Equations are presented for work done by a jet of fluid, head losses in the hydraulic induction circuit, and for determining the required pump motor size. The cooling system was tested by fitting it to a 24-spindle two-way machine, and drilling aluminum alloy components with gun boring drills, such as the one shown in Fig. 2. The tests showed that the above formula could be used to design an effective cooling system.

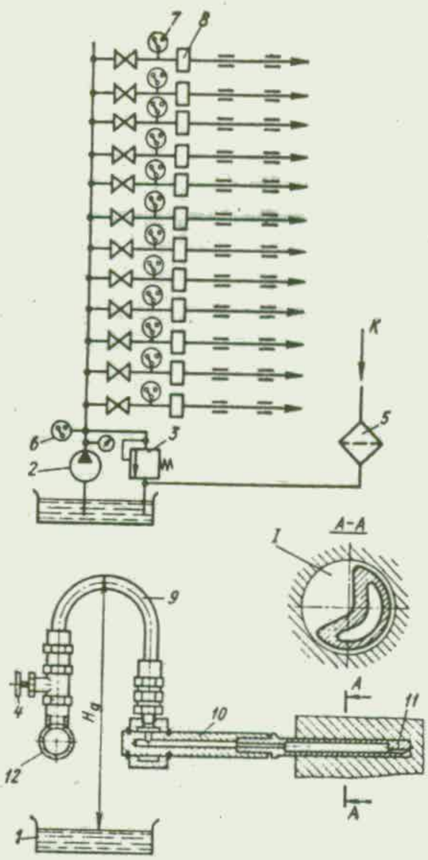


Fig. 1.
Diagram of cooling system (arrow K indicates coolant return).

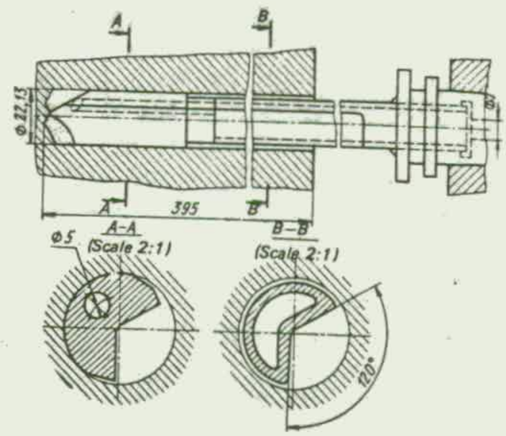


Fig. 2

1. GARINA, T. I., et al

2. MORE ACCURATE POSITIONING OF HOLES IN DRILLING

3. MACHINES AND TOOLING, Vol. 43, No. 9, 1972, pgs. 47-48

4. Tests show that as the drill starts to cut, its tip is displaced by some amount known as the initial displacement, which depends on the accuracy of drill-grinding and setting.

   Figures 1 and 2 show initial displacement a and deflexion δ of the hole axis plotted against speed n and feed rate s. Analysis of the results indicates that the drill overhang has a significant influence on hole positioning accuracy. The following functional relationships are recommended for practical use:

$$a = C_1 - C_2 s + C_3 s^2 \cdot 10^3;$$

$$a = C_1 - C_2 n \cdot 10^{-6} + C_3 n^2 \cdot 10^{-9};$$

$$\delta = C_1 - C_2 s + C_3 s^2 \cdot 10^3;$$

$$\delta = C_1 - C_2 n \cdot 10^{-6} + C_3 n^2 \cdot 10^{-9}.$$

   where n is the drill speed (rev/min); s is the feed rate (mm/rev); C_1, C_2 and C_3 are coefficients, and can be determined from the Table.

   With a known initial displacement it is possible to determine the hole axis deflexion by using the following relationships derived on the basis of correlation analysis:

$$\delta_{10} = 0.01 + 0.116a;$$

$$\delta_{16} = 0.01 + 0.10a$$

   where δ_{10} and δ_{16} are the deflexion of the hole axis (mm) with the drill set in the chuck with overhangs of L = 10d and 16d respectively.

   In practice it is possible to avoid errors of entry hole position by correcting the workpiece setting on the basis of experimental initial displacement values.

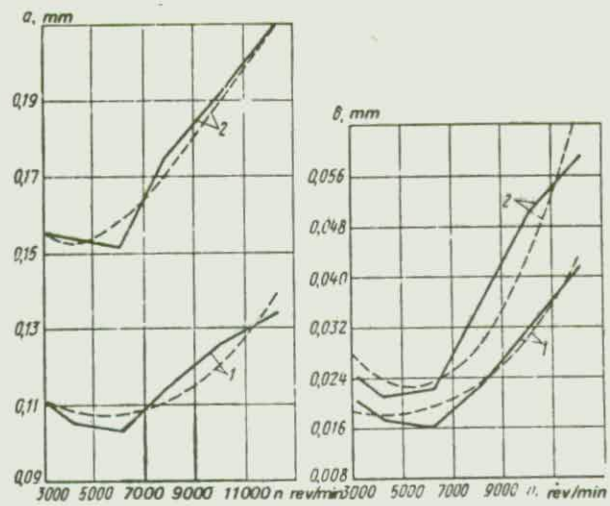


Fig. 1.
Initial displacement and deflexion of hole axis plotted against drill speed with s = 0,006mm/rev: curves 1 – with L = 10d, 2 – with L = 16d, broken lines – theoretical values.

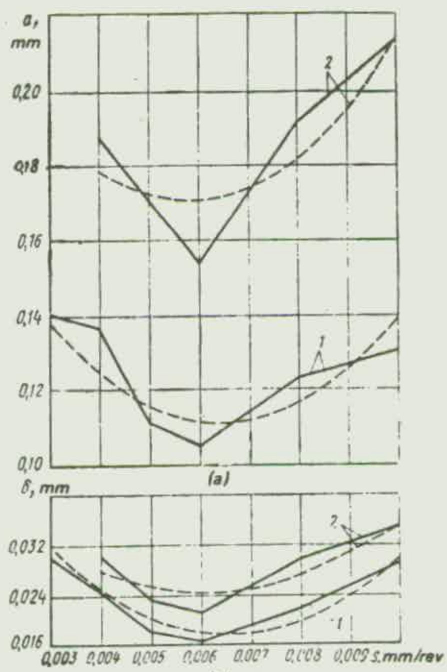


Fig. 2.
Initial displacement and deflexion of hole axis plotted against feed with n = 4100rev/min: curves 1 and 2 – as in Fig. 1.

1. SPUR, G., AND HOFFMANN, V.

2. WERKZEUGVERSCHEISS BEIM BOHREN VON GEFÜLLTEN POLYAMIDEN (Drill Wear When Drilling Reinforced Nylon)

3. ZEITSCHRIFT FÜR WIRTSCHAFTLICHE FERTIGUNG, Vol. 67, No. 2, pp. 61-64, 1972

4. In recent years, thermoplastic materials have been progressively developed and the plastic is increasingly demanded by new applications.

   Using reinforcement like fiberglass in the basic raw material, the material properties are substantially improved in terms of tensile strength and stability to temperature.

   In this paper, the results of the investigation on the tool wear of twist drill when drilling thermoplastic materials is described.

   Tool wear is caused by the stresses produced in the materials being machined. These stresses should be based on mechanical and thermal effect, which act at the near edge of the margin and result in a change of geometry in the tool edge. It also causes an increase of cutting forces, cutting temperature, and a deterioration of surface finish.

   However, thermoplastic materials have minimized the effect of temperature on drill wear, because the effective cutting temperature is less than 250^{o} C.

   The investigation was conducted on an N/C machine having a drill diameter of 3 mm.

   The drill wear, as a function of total drilling length (depth) for five different plastic materials, is shown in Fig. 1. The effect of feed rate on the drill wear and drilling depth is described in Fig. 2, while the effect of drilling speed on the drill wear as a function of total drilling length is shown in Fig. 3.

   The thrust force is increased as drilling length is increased while torque is steady throughout the total drilling length, and this is presented in Fig. 4.

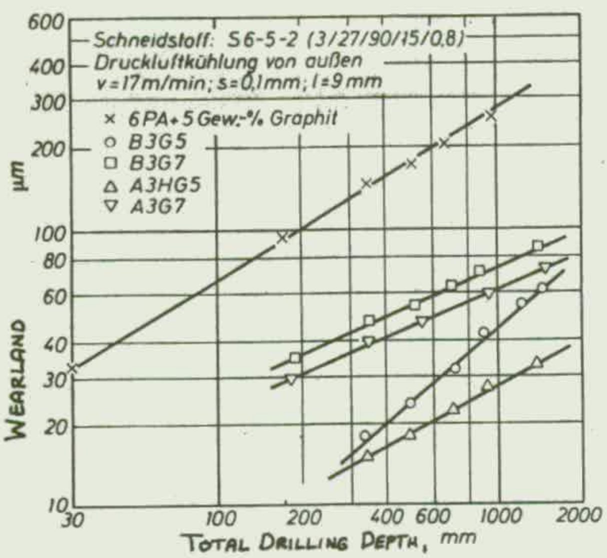


Fig. 1

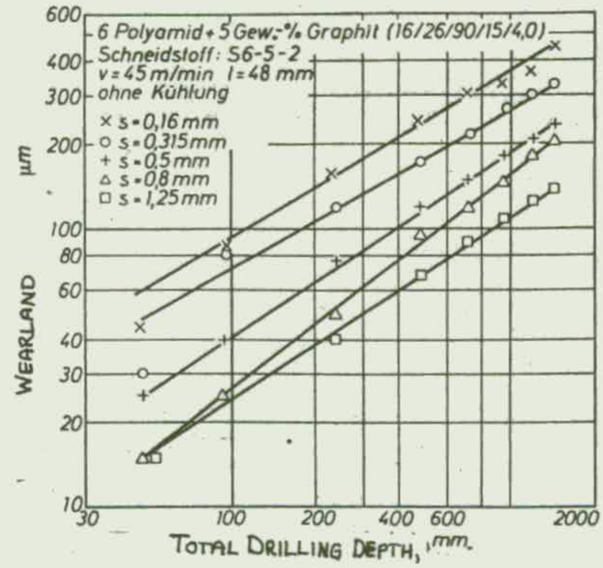


Fig. 2

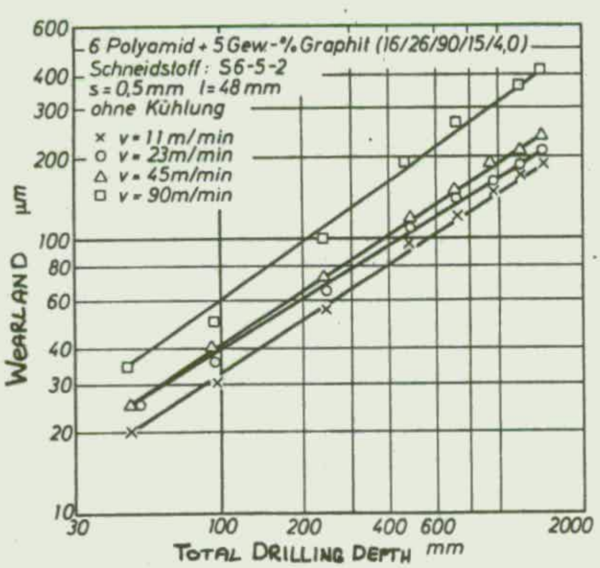


Fig. 3

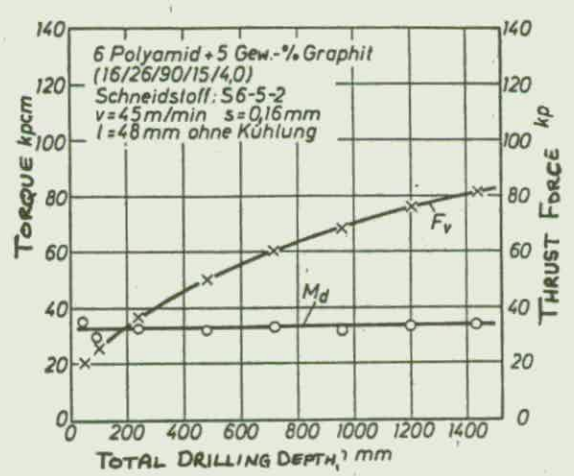


Fig. 4

1. DELLINGER, T. B., LIFESAY, B. J.

2. DIAMOND BIT DRILLING RESEARCH

3. TRANSACTIONS OF THE ASME - JOURNAL OF ENGINEERING FOR INDUSTRY, Series B, February 1973, pp. 256-261

4. Fundamental relationships of the parameters; penetration rate, bit weight, rotary speed, bit horsepowers, flow rate, and pressure were developed using eight full scale oilfield diamond drilling bits under laboratory conditions. One thousand five hundred data points, with all the parameters, were analyzed with 642 plots and 131 multiple-regression analyses. The hydraulic lift under the diamond bit has been accounted for in order to obtain relationships of mechanical bit weight with torque and penetration.

Sixteen different types of plotted relationships were made. Because of space limitations, only six characteristic types of the 616 individual machine plots made are reproduced and included in this paper.

Analysis of Individual Type Plots. The plots of the data are discussed individually by type of plot.

Effect of Bit Weight on Penetration Rate. Fig. 1 shows penetration rate as a function of indicated bit weight with variable rotary speed.

In the plot, because of hydraulic lift, the zero-penetration-rate intercept is to the right of the origin. As could be seen in other similar plots, as flow rates were increased, the pressure drop across the bit increased; consequently, hydraulic lift increased and comparable penetration rates were shifted to the right.

The indicated bit weight is the weight observed in field tests and is the weight reported by other authors. Unless hydraulic lift is taken into account, an increased flow rate will usually decrease penetration rate of any bit that has any pressure drop across the face.

Fig. 2 presents penetration rate as a function of mechanical bit weight with variable rotary speed. Mechanical bit weight is the indicated bit weight less the hydraulic lift and is the interactive mechanical force between the diamonds and the rock. In this case, the zero-penetration-rate intercept is very near the origin because the hydraulic lift has been discounted and Carthage marble is such that any measurable mechanical bit weight produced a penetration.

4. (Continued)

In general, with all but one of the independent parameters held constant, increased bit weight produced an increased penetration rate with an increasing rate of change.

Effect of Rotary Speed on Penetration Rate. Fig. 3 presents penetration rate as a function of rotary speed with variable mechanical bit weight.

In general, with all but one of the parameters held constant, an increased rotary speed produced an increased penetration rate with a decreasing rate of change.

Effect of Torque on Penetration Rate. Fig. 4 shows penetration rate as a function of torque with variable RPM.

With all but one independent parameter held constant, an increase in bit weight produced an increase in torque and an increase in penetration rate.

At any constant bit weight, an increase in rotary speed produced an increase in penetration rate but a decrease in torque.

Effect of Bit Weight on Penetration Rate With Variable Flow Rate. Fig. 5 presents penetration rate as a function of mechanical bit weight with variable flow rate in the legend. These plots show that flow rate has very little effect on penetration rate. With the hydraulic lift removed, any cleaning effect should be evident with a stratification of the legend numbers, and constant flow-rate lines could be constructed by connecting like symbols in the same manner as was done in constructing the previous plots for rotary speed and bit weight. However, in none of the 69 prepared plots was this possible.

Effect of Bit Horsepowers on Penetration Rate. From 37 plots, it was observed that hydraulic horsepower did not significantly effect the penetration rate.

It should be noted that even though the foregoing was true in the laboratory experiments, reports of field conditions indicate that increased hydraulic horsepower does increase penetration rate. The difference in effects obtained by field tests and laboratory tests can be attributed to pressure,mud, and fluid properties. The laboratory drilling was with clear water and a brittle rock; field drilling is with mud and often with plastic formations.

Penetration rate increased as rotary mechanical horsepower increased. However, since rotary mechanical horsepower is proportional to the product of torque and rotary speed, a plot of the more basic torque or rotary speed should be more significant.

4. (Continued)

Effect of Rotary Speed on Penetration Per Revolution. Fig. 6 presents penetration per revolution as a function of rotary speed with a variable mechanical bit weight.

With the log-log plot, the straight lines at constant weight show decreasing penetration per revolution as rotary speed is increased.

Effect of Bit Weight on Penetration Per Revolution. An increase in bit weight produced an increase in penetration per revolution with an increasing rate of change.

Effect of Torque on Penetration Per Revolution. With a constant RPM, an increase in weight caused an increase in torque and an increase in penetration per revolution. The increase in torque was directly proportional to the increase in penetration per revolution.

Effect of Bit Weight on Torque. With all but one independent parameter held constant, an increased bit weight produced an increased torque with an increasing rate of change.

Conclusions. Conclusions reached in this study are:

1. The hydraulic-lift effect on the diamond bit must be accounted for to obtain net bit load on the rock.

2. The analyses of the data produced the following relationships:

   A $PR = e^{A}(BWM)^{1.2}(RPM)^{0.9}(GPM)^{0.05}$, (1)

   B $PR = e^{E}(TORQ)^{1.05}(RPM)^{1.05}(GPM)^{0.1}$, (2)

   C $PR = e^{I}(BWI)^{J}(RPM)^{0.9}(GPM)^{L}$, (3)

   where $J \approx 1.3$ to 1.6, and $L \approx -0.1$ to -0.6.

   D Values for A, E, and I varied widely by bit type. Values for all the exponents varied according to bit type and experimental conditions.

   E Equations (1) and (2), with correct selection of exponents, were good predictors for all bits.

   F Equation (3) was not a good predictor for bits with hydraulic lift.

3. With all but one parameter held constant, further relationships were:

4. (Continued)

A Increases in mechanical bit weight resulted in:

(1) increased bit torque with an increasing rate of change;

(2) small increases in pressure drops across the bit due to decreasing flow area as the diamonds penetrate the rock.

B Increases in rotary speed resulted in:

(1) small decreases in bit torque;
(2) decreased penetration per revolution.

C Increases in flow rate resulted in:

(1) increased pressure drops across the bit;

(2) increased hydraulic lift on the bit, with a resultant decreased mechanical bit weight;

(3) very small increases in penetration due to cleaning.

D Bit pressure drops and bit hydraulic horsepower showed no significant effects on penetration.

4. Torque correlated with penetration rate as closely as did mechanical bit weight.

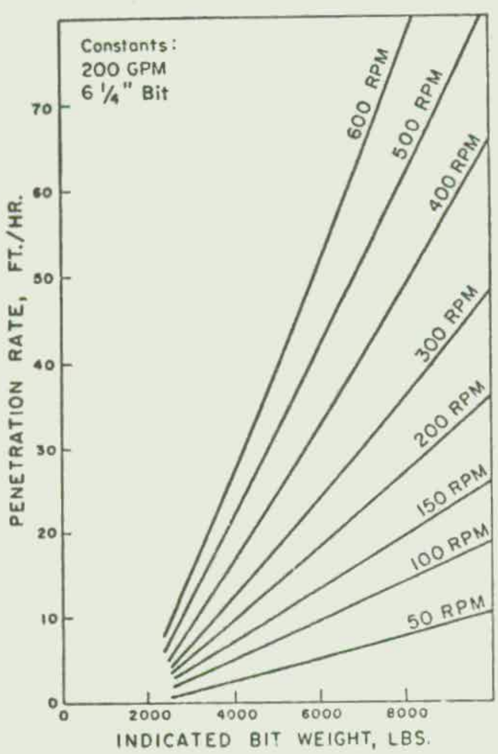


Fig. 1

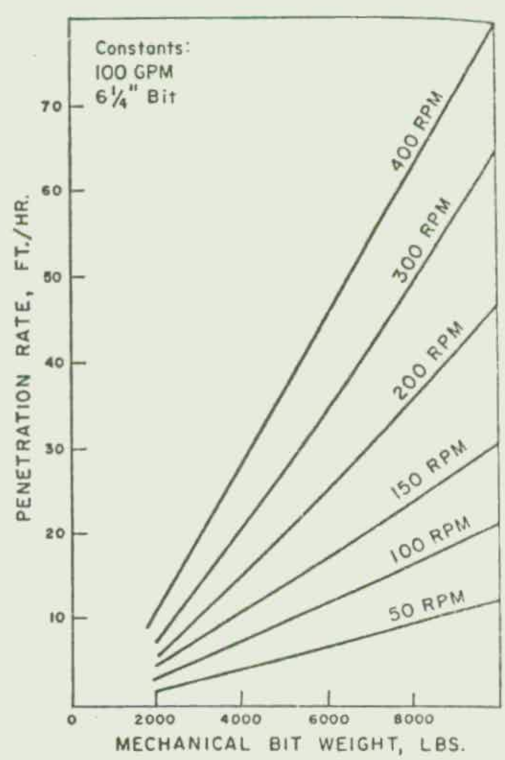


Fig. 2

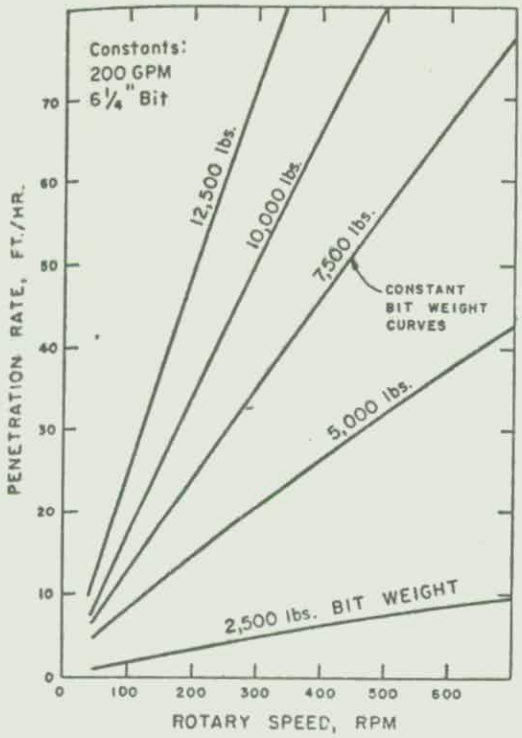


Fig. 3

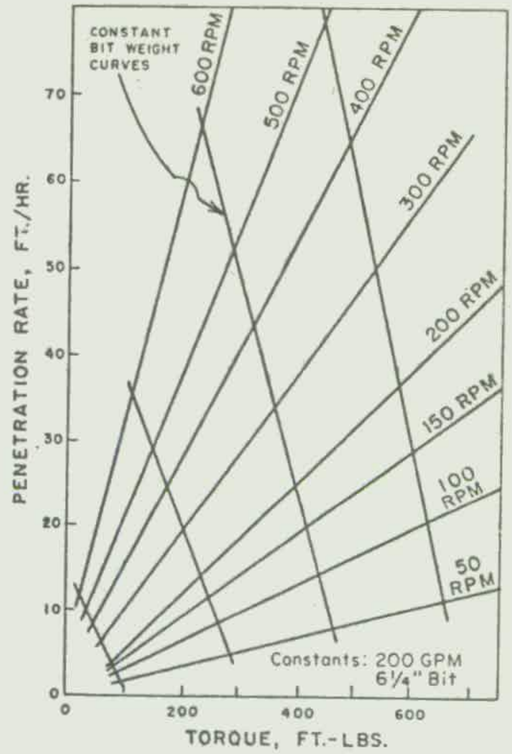


Fig. 4

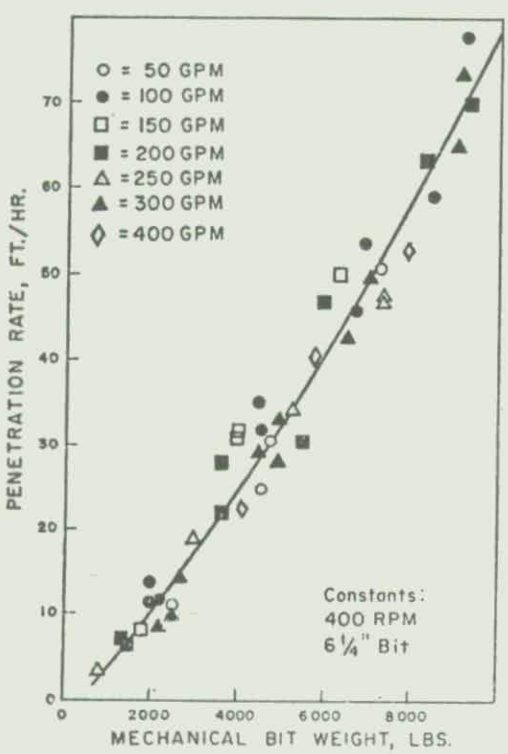


Fig. 5

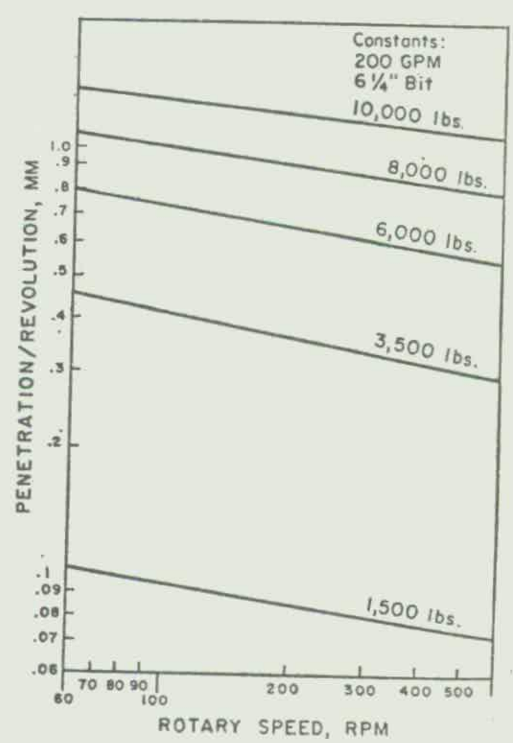


Fig. 6

1. ERMER, D. S., and SHAH, B. V.

2. ANALYTICAL SENSITIVITY STUDIES OF THE OPTIMUM MACHINING CONDITIONS FOR MILLING, DRILLING, REAMING, AND TAPPING

3. TRANSACTIONS OF THE ASME JOURNAL OF ENGINEERING FOR INDUSTRY, February, 1973, pp. 312-316

4. For any total unit cost (C_u') greater than the minimum unit cost, C_u, there are two cutting speeds, V_L and V_H where $V_L < V_{min} < V_H$ as seen in Fig. 1. It is possible then, to deviate from V_{min}, select an appropriate speed which meets the specified constraints of the operation and at the same time lies between V_L and V_H, without having an increase in costs higher than the predetermine value (C_u'). To determine the V_L - V_H range a nondimensional ratio, p, is formed as follows:

$$p = \frac{\text{variable costs}}{\text{minimum variable costs}}$$

$$p = \frac{C_u - c_o t_h}{C_{u(min)} - c_o t_h}$$

On simplification, by use of equations (2) and (3), the ratio is

$$p = \frac{1}{q} \left[\frac{1}{n+1} \left[1 + nq^{\frac{n+1}{n}}\right]\right]$$

where q is a nondimensional ratio given by

$$q = \frac{V}{V_{min}}$$

Values of the ratio p versus the ratio q are plotted in Fig. 2 for different values of the tool-life exponent. In Fig. 2 it can be seen that the sensitivity of the variable costs to deviations in speed from the theoretical optimum speed decreases as the value of Taylor's exponent n increases; and that this decrease is greater for deviations above V_{min}, i.e., where q = 1.0. Although the expression obtained for p is different from that obtained for turning [4], where $p = 1/q(1 - n + nq^{1/n})$, the nature of the curves is similar to that for turning, were p versus q for turning is given in Fig. 3. From a comparison of Figs. 2 and 3 it can be observed that values of p for a given change in speed from V_{min} are higher in Fig. 2 than those in Fig. 3. The difference between

4. (Continued)

the two graphs increases as the value of n increases, and the difference is more significant for speeds higher than V_{min}.

More importantly, however, is the fact that the amount of increase in the total unit cost as measured by the ratio p depends on the ratio of the constant unit cost to the variable unit cost, and the larger the constant cost the less C_u is affected by deviations from V_{min}.

Another nondimensional ratio, w, is defined as

$$w = \frac{\text{constant cost}}{\text{minimum variable cost}}$$

The increase in the total unit cost due to a deviation from V_{min} is given by the ratio

$$Z = \frac{\Delta C_u}{C_{u(min)}} = \frac{p-1}{1+w}$$

By putting p - 1 as a function of q for a given n (with w = 0) as shown on the right side of Fig. 4, the left side is a nomograph for finding the percentage increase, Z, given (p - 1), n, and w. That is, if n = 0.25, w = 0.25, and q_L = 0.8 and q_H = 1.2; then from Fig. 4, the percentage increase in costs is approximately 6.5 percent and 7.5 percent for q_L and q_H, respectively.

SENSITIVITY ANALYSES FOR DRILLING OPERATIONS

Another important machining operation is drilling, and an economic sensitivity analysis is also possible, assuming a tool life equation of the same form as in turning, i.e., $VT^n = C$, but where T is measured in inches drilled. The total unit cost in drilling is given by

$$C_u = c_o t_m + \left[\frac{L}{T}\right] (c_o t_c + c_t) + c_o t_h$$

where

t_h = handling time, min/workpiece

$$= \begin{matrix}\text{rapid} \\ \text{traverse} \\ \text{time}\end{matrix} + \begin{matrix}\text{load and} \\ \text{unload} \\ \text{time}\end{matrix} + \begin{matrix}\text{set-up} \\ \text{time}\end{matrix}$$

$$= \frac{2au + L}{r} + t_L + \frac{t_o}{N_L}$$

4. (Continued)

and where a is the approach distance, u is the number of holes of the same diameter in the workpiece, r is the rapid traverse rate, L is the sum of lengths of all holes of the same diameter, t_L is the time to load and unload the workpiece, t_o is the time to set-up the drill for operation, and N_L is the lot size. The feeding time, t_m, is given by

$$t_m = \frac{L}{f_r \cdot N} = \frac{\pi DL}{12 f_r V}, \text{ minutes}$$

where f_r is the feed per revolution, N is the speed in rpm or V is the cutting speed in fpm, and D is the diameter of the drill. The drill cost/workpiece, c_t, is given by

$$c_t = \begin{matrix}\text{drill}\\ \text{depreciation}\\ \text{cost}\end{matrix} + \begin{matrix}\text{drill}\\ \text{resharpening}\\ \text{cost}\end{matrix}$$

$$= \frac{c}{k_1 + 1} + G \cdot t_s$$

where c is the purchase cost of the drill, t_s is the time to resharpen the drill, G is the operating cost on the tool grinder, and k_1 = number of times the drill is sharpened before being discarded.

The cutting speed for minimum cost can be found by differentiating the cost equation (13) with respect to V, equating it to zero, and solving for

$$V_{min} = \frac{C^{1/(n+1)}}{\left[\dfrac{12 f_r \left[t_c + \dfrac{c_t}{c_o}\right]}{\pi n D}\right]^{n/(n+1)}}$$

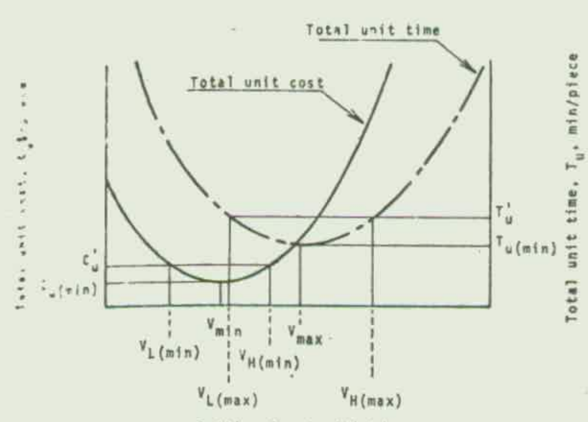


Fig. 1 Total unit cost and total unit time versus cutting speed

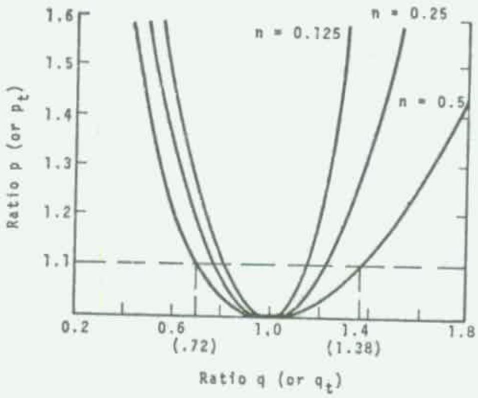


Fig. 2 Ratio p(or p_t) versus ratio q (or q_t) for the milling sensitivity relationship

$$p = \left[\frac{1}{q}\,\frac{1}{(n+1)}\,\{1 + n(q)^{(n+1)/n}\}\right]$$

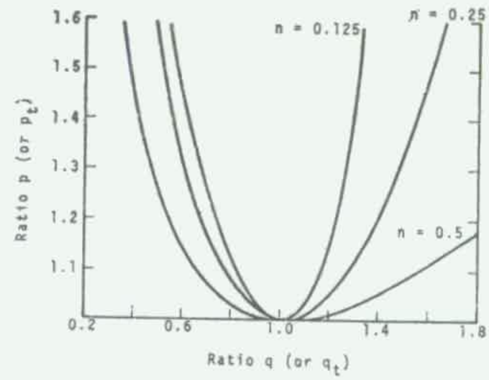


Fig. 3 Ratio p (or p_t) versus ratio q (or q_t) for the turning sensitivity relationship

$$p = \frac{1}{q}\left(1 - n + nq^{\left(\frac{1}{n}\right)}\right)$$

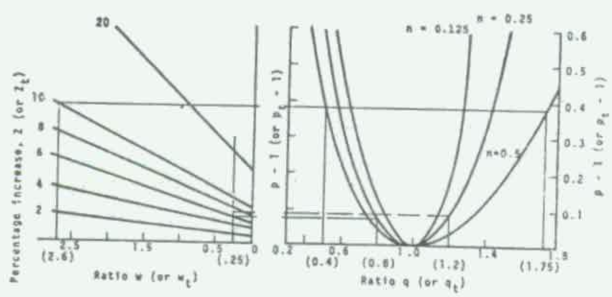


Fig. 4 Nomograph for milling, drilling, reaming and tapping to find the percentage increase in cost (time) versus the ratio $q = V/V_{\min}$ (or $q_t = V/V_{\max}$) and the ratio w (or w_t) of constant cost (time) to minimum variable cost (time)

1. ARMAREGO, E. J. A., and ROTENBERG, A.

2. AN INVESTIGATION OF DRILL POINT SHARPENING BY THE STRAIGHT LIP CONICAL GRINDING METHOD - I. BASIC ANALYSIS

3. INTERNATIONAL JOURNAL OF MACHINE TOOL DESIGN AND RESEARCH, Vol. 13, No. 3, Sept., 1973, pp. 155-164

4. Twist drills could be regarded as some of the most geometrically complex tools in common use. In spite of the considerable and valuable efforts made to improve our understanding of the geometry, cutting action and drill performance, there is much to be learned about drills and drilling. Some ambiguity exists in the geometrical definitions and diagrammatic representations of twist drills in standards and handbooks. Handbooks refer to two clearance angles on the flank, namely: the lip clearance (or relief) angle at the lips specified at the outer corner of the drill and a clearance angle involving the outer corner and another point on the flank at the drill circumference. Standards refer to the lip clearance angle only, although the diagrammatic representations are inconsistent with the verbal definitions given for this angle. The lip clearance angle in Fig. 1(a) should be illustrated in a plane normal to the drill radius and parallel to the drill axis rather than in the plane shown in the diagram. Figure 1 also shows the various ways by which the "same" clearance angle has been illustrated, from which the ambiguity is obvious.

Thorough studies of actual drill sharpening techniques have been seriously lacking in the literature although drill point sharpening machines based on conical grinding methods have been used early this century. Handbooks give vague diagrams, such as that shown in Fig. 2, in an attempt to illustrate the basic principles.

In this investigation the conical grinding concept was reconsidered by using more direct analytical methods with a view to derive equations for describing the drill geometry and for designing drill point grinders. An attempt to arrive at the grinding parameters for optimum drill geometry was made. The desirability of geometrically similar drills with respect to the drill sharpening method was studied. The basic features of a few actual drill point grinders was investigated to test whether the conical grinding concept is applicable as previously suggested.

From the given drill specification only three general expressions relating the drill geometry to four basic grinding parameters have been found. As a result, an infinite number of grinding cones may be used to sharpen a drill to the given specification. It is apparent that a further equation should be sought to establish a unique grinding cone and drill point geometry for a given specification.

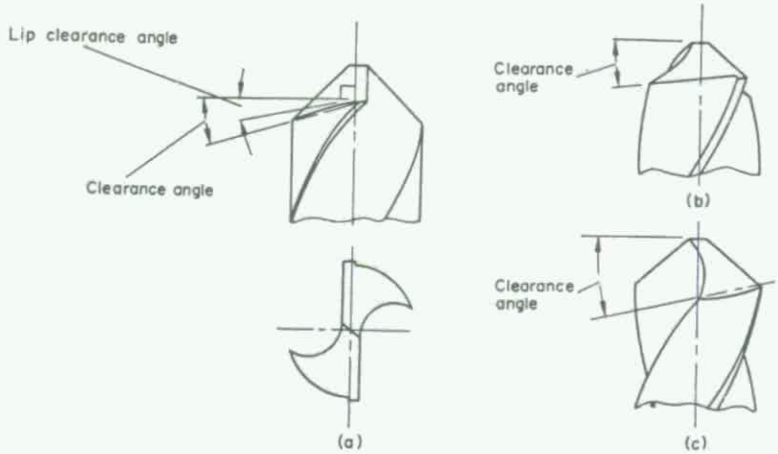


FIG. 1. Various common methods of illustrating the clearance angles on a drill.

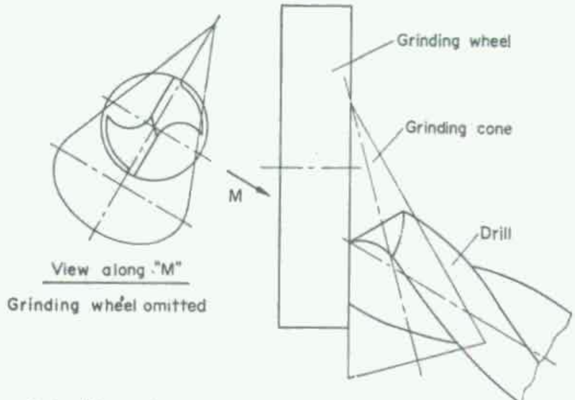


FIG. 2. An illustration of conical grinding often shown in handbooks.

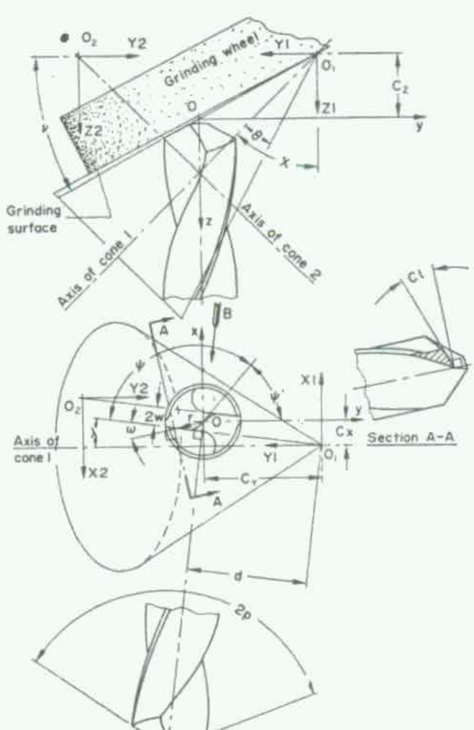


FIG. 3. The relevant geometry of the conical grinding method for straight lip drills.

TABLE 1. EXAMPLES OF VARIOUS GRINDING CONE PARAMETERS WHICH SATISFY A GIVEN DRILL SPECIFICATION

Drill specification				Grinding cone parameters					Galloway's parameter ÷ diameter
$2W/D$	$2p°$	$Cl_0°$	$\psi°$	Cx/D	Cy/D	$\lambda°$	$\theta°$	$\chi°$	d/D
0·16	118	14	120	0·2777	0·2439	36·2	51·1	10	0·3609
				0·2370	0·3898	21·2	45·2	15	0·4491
				0·2105	0·5056	14·2	39·8	20	0·5418
				0·1958	0·6365	10·2	34·6	25	0·6611
				0·1826	0·7845	7·4	29·4	30	0·8015
				0·1732	0·9824	5·4	24·3	35	0·9943
				0·1641	1·2635	3·8	19·2	40	1·2716
				0·1649	1·4701	3·3	17·2	42	1·4772*
				0·1630	1·8268	2·6	14·1	45	1·8323
				0·1549	2·8610	1·5	9·1	50	2·8640
0·16	118	14	135	0·1636	0·0881	36·2	51·1	10	0·1677
				0·1503	0·1664	21·2	45·2	15	0·2095
				0·1402	0·2279	14·2	39·8	20	0·2553
				0·1335	0·2903	10·2	34·6	25	0·3093
				0·1293	0·3494	7·9	30·5	29	0·3639*
				0·1282	0·3662	7·4	29·4	30	0·3796
				0·1242	0·4634	5·4	24·3	35	0·4730
				0·1201	0·6010	3·8	19·2	40	0·6077
				0·1183	0·8418	2·6	14·1	45	0·8463
				0·1142	1·3054	1·5	9·1	50	1·3080
				0·1120	3·0541	0·6	4·0	55	3·0551
0·16	118	16	120	0·3759	0·2268	48·4	52·7	10	0·4316
				0·3195	0·4528	26·9	46·0	15	0·5484
				0·2823	0·6138	17·9	40·3	20	0·6709
				0·2574	0·7784	12·7	34·9	25	0·8159
				0·2396	0·9683	9·3	29·7	30	0·9943
				0·2238	1·2193	6·7	24·5	35	1·2371
				0·2166	1·6233	4·8	19·3	40	1·6357
				0·2017	2·1739	3·2	14·2	45	2·1817
				0·1968	3·5207	1·9	9·1	50	3·5253*
0·16	118	16	135	0·1844	0·0567	48·4	52·7	10	0·1755
				0·1736	0·1653	26·9	46·0	15	0·2259
				0·1613	0·2392	17·9	40·3	20	0·2772
				0·1524	0·3126	12·7	34·9	25	0·3384
				0·1476	0·3806	9·9	30·7	29	0·4004*
				0·1461	0·3970	9·3	29·7	30	0·4154
				0·1397	0·5039	6·7	24·5	35	0·5168
				0·1359	0·6619	4·8	19·3	40	0·6709
				0·1320	0·9272	3·2	14·2	45	0·9332
				0·1289	1·4737	1·9	9·1	50	1·4772
				0·1292	3·5238	0·8	4·1	55	3·5253

1. ARMAREGO, E. J. A., and ROTENBERG, A.

2. AN INVESTIGATION OF DRILL POINT SHARPENING BY THE STRAIGHT LIP CONICAL GRINDING METHOD - II. A CRITERION FOR SELECTING A SOLUTION

3. INTERNATIONAL JOURNAL OF MACHINE TOOL DESIGN AND RESEARCH Vol. 13, No. 3, Sept. 1973, pp. 165-182

4. A search for an extra condition to obtain a unique and optimum set of grinding parameters is made.

   It is shown that a unique solution is not possible when the grinding parameter λ is made equal to zero. Furthermore the numerical values of the angles at the drill point for the various possible grinding cones when $\lambda = 0$ are not consistent with the recommendations given in handbooks.

   Upper and lower limits of the semi-cone angle θ are located by studying the drill flank geometry in the annular region between the outer radius and the chisel edge corner radius. The upper value of θ is based on the limiting circumferential clearance angle needed to avoid interference between the flank and the surface machined by the lips. The lower limit of θ is found by ensuring that the whole drill flank can be ground. According to the geometrical investigation of the chisel edge region the smaller semi-cone angles give increased rake and clearance angles and smaller wedge angles which should lead to improved cutting conditions in this region.

   It appears that the semi-cone angle should be selected as small as possible subject to restrictions such as the lower limit of θ or a specified circumferential clearance angle. The lowest permissible θ represents the criterion which provides a unique solution to the grinding method.

1. ARMAREGO, E. J. A., and ROTENBERG, A.

2. AN INVESTIGATION OF DRILL POINT SHARPENING BY THE STRAIGHT LIP CONICAL GRINDING METHOD - III. DRILL POINT GRINDER DESIGN FEATURES

3. INTERNATIONAL JOURNAL OF MACHINE TOOL DESIGN AND RESEARCH, Vol. 13, No. 4, December 1973, pgs. 233-241

4. A brief survey of the geometry of some actual drill point sharpeners has been undertaken. The two grinders shown in Figs. 1 and 2 appeared to be based on a conical grinding concept since the drills were ground by rotating them about a fixed axis with respect to the grinding wheels. In the third case illustrated in Fig. 3 (a common mechanism type grinder) the drill was made to rotate about its axis, translate in the axial direction and oscillate about an axis normal to the horizontal drill and grinding wheel axes. The grinding wheel axis was stationary and the drill was ground on the periphery of the wheel.

   A brief study of the three actual grinders has shown that these grinders are not designed according to the straight lip conical grinding model. The main features of a grinder based on the analyses developed in this investigation are discussed. It is shown that drills with geometrically similar drill points lead to fewer adjustments on the grinder and are therefore easier to grind correctly than the drills used in practice.

   This investigation has shown that the straight lip conical grinding method permits independent variations of the angles at the drill point. This feature is desirable when studying the effect of geometry on drill performance.

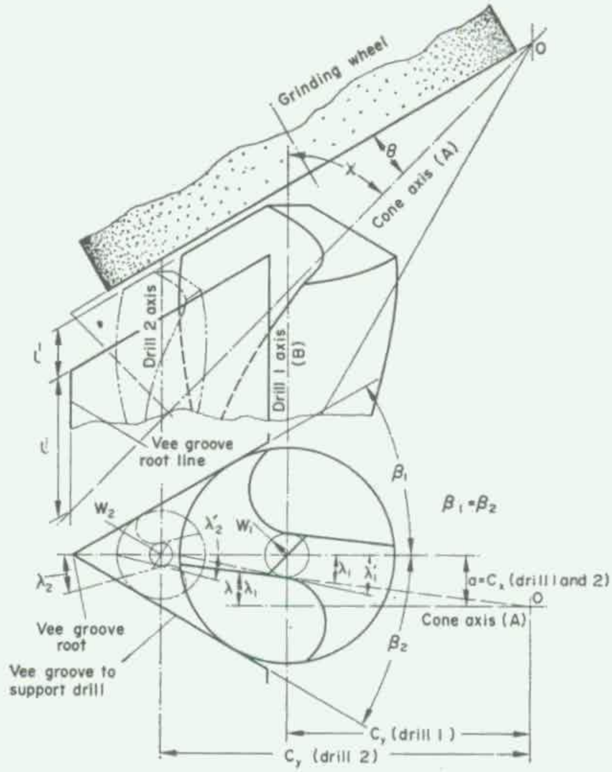


FIG. 1. Features of an inexpensive drill grinding attachment.

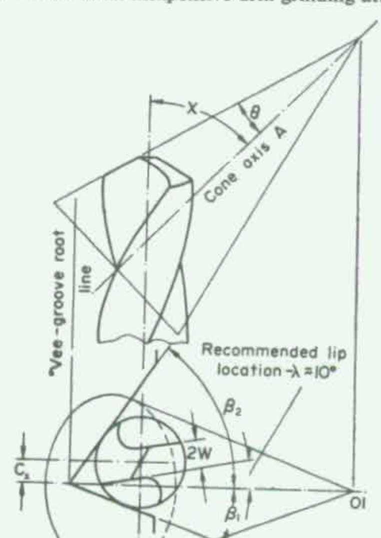


FIG. 2. Salient geometry of a conical type drill point grinder.

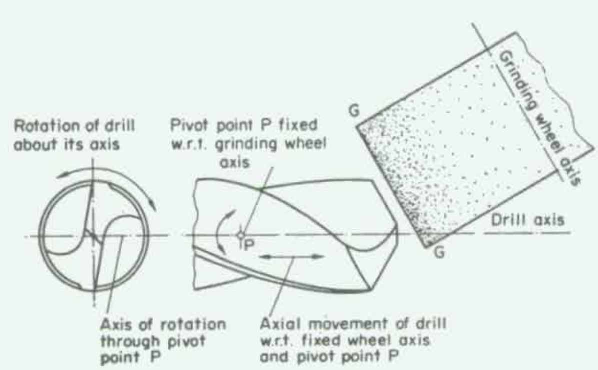


FIG. 3. General features of a common mechanism type drill point grinder.

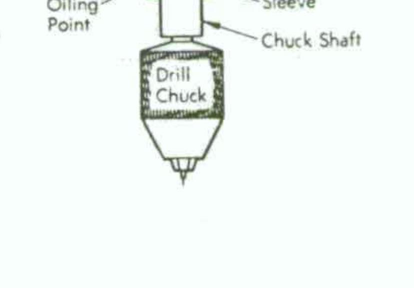
1. ANONYMOUS

2. CHUCK FOR DELICATE DRILLS

3. MACHINE AND TOOL BLUE BOOK, September 1973, p. 129

4. The assembly shown in the diagram utilizes an oil firm to couple power between the drive spindle and the drill chuck. The chuck shaft is machined to a sliding fit for a sleeve of convenient diameter; the upper part of the chuck shaft is equipped with a stop, which may be a pin, washer, or screwed-on cap. The interface between the chuck shaft and the sleeve is kept generously lubricated with oil; a low viscosity oil is usually sufficient, but higher viscosities may be required to transfer more power from the sleeve to the chuck.

   The weight of the chuck and its shaft usually provides sufficient pressure for small drills, but additional cutting pressure can be obtained by adding weight to the chuck or to the top of the shaft. In any event, the speed of rotation of the chuck should be kept low, and the weight of the chuck and its shaft should be at a minimum for a given drill in order to keep "fly-wheel" energy storage below that required to break the drill. When all factors have been properly controlled, sufficient pressure will be automatically applied to the drill point; the chuck simply stops rotating when the drill jams.



1. DAVIDSON, A. M.

2. DRILLING ML5 MAGNESIUM ALLOY

3. RUSSIAN ENGINEERING JOURNAL, Vol. 53, No. 7, 1973, pp. 71-72

4. Results are presented of a study of cutting forces in the drilling of ML5 magnesium alloy. The test specimens were 100mm diameter, 40mm long pressure die castings.

Drilling was done with twist drills of R18 high-speed steel with the following geometry: point angle $2\phi = 90$; rake angle $\gamma = 10^{\circ}$; lip clearance angle $\alpha = 12^{\circ}$; land width $k = 0.1d$ and helix angle $\omega = 30^{\circ}$.

Drill diameters, feed rates and drill lives were determined by production requirements. Drills from $d = 6$mm to $d = 14$mm diameter were used, with a feed rate of $s = 0.14$-0.56mm/rev and a cutting speed in the range $v = 19$-53m/min.

Mathematical analysis of the test results gave the following relationships for the drilling of ML5 magnesium alloy:

$$P_o = 5.73\, d^{1.04} s^{0.6} \text{kgf}; \qquad (1)$$

$$M_t = 0.61 d^{1.88} s^{0.6} \text{ kgf.cm.} \qquad (2)$$

Table 1 shows measured values of force P_o and values calculated from equation (1) with various combinations of d and s. These show that equation (1) can be used for practical purposes.

To enable measured torque values when using drills of various diameters with various feed rates to be compared with values calculated from equation (2), the graph shows curves which indicate that equation (2) can be used for practical calculations.

Table 1

Test No.	Drill diameter d (mm)	Feed s (mm/rev)	Measured axial force P_0 (kgf)	Calculated axial force P_0 (kgf)
1	14	0,14	28,49	27,39
2	6	0,56	27,15	26,08
3	6	0,14	11,33	11,35
4	14	0,56	62,40	62,92
5	10	0,35	29,62	33,45
6	10	0,28	27,95	29,24
7	11,7	0,28	33,17	34,44

1. VINOGRADOV, A. A., et al

2. DRILLING VT 18 TITANIUM ALLOY AND KH 18N10T STAINLESS STEEL

3. RUSSIAN ENGINEERING JOURNAL, Vol. 53, No. 7, 1973, pp. 72-74

4. Tests to determine drill life were performed by drilling 12 mm diameter blind holes 30 mm deep in specimens of titanium alloy without coolant, whereas in the case of KH18N10T stainless steel, oil was used. The optimum tool geometry (Fig. 1) was as shown in Table 1.

Figure 2 shows results of tests to determine T = f(v) for drilling titanium alloy with s = 0.058 mm/rev feed (D = 12 mm) without coolant and T = f(D) for drilling with v = 31.5 m/min and s = 0.058 mm/rev (hole depth 2.5D). For comparison, results of tests using a D = 12 mm diameter drill of R18 high-speed steel without coolant and a water emulsion are also given.

It will be seen that when drilling with normal life (12-14 min) and enhanced life (80-100 min), the cemented-carbide drill gives 5.8 and 4 times greater removal than a high-speed steel drill. The use of a coolant increases the life of a high-speed steel drill by a factor of 10, while removal can be increased by only 30%.

To determine T = f(s) (Fig. 3), blind and through holes were drilled in specimens of VT18 titanium alloy without coolant, and blind holes were drilled with water emulsion and oil coolants. The test results showed that the most efficient coolant is a water emulsion (drill life more than doubled).

Figure 4 shows the results of tests using drills having a cutting section of VK10M and KV15M carbides and R18 steel. It will be seen from Fig. 4 that VK10M carbide gives double the life or 34% greater removal than VK15M carbide. Compared with high-speed steel drills, drills of VK10M carbide give 83% greater removal with a life of T = 60 min and 150% greater removal with T = 20 min.

Table 1

Workpiece material	Drill geometry								
	γ_N	α_N	α_x	2φ	$2\varphi_0$	$\Delta\varphi$	l	b	a
VT18 alloy . .	+10°	15°	30°	125°	—	6°	0,2D	—	0,08D
KH18N10T steel .	∓12°	12°	30°	120°	80°	6°	0,2D	0,15D	0,08D

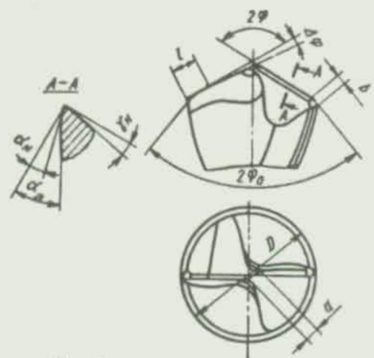


Fig. 1.
Drill cutting-section geometry.

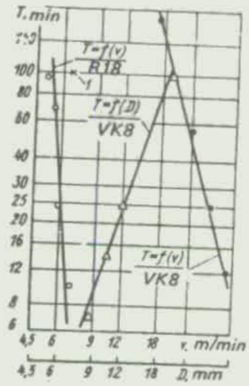


Fig. 2.
Relationship between life T of drills with cemented-carbide heads, cutting speed v and drill diameter D. Relationship between life of drill of R18 steel (D = 12mm) and v when drilling VT18 titanium alloy without coolant (point 1 with water emulsion cooling).

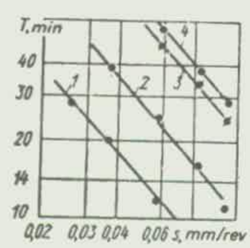


Fig. 3.
Relationship between life T of VK8 drills and feed rate s when drilling D=12mm diameter and 30mm deep holes with v = 31,5m/min in VT18 titanium alloy:
1, 2 – without coolant, through and blind holes respectively;
3, 4 – cooling with LZSOZHZ oil and 5% emulsion respectively, blind holes.

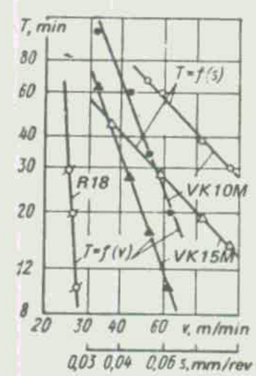


Fig. 4.
Life T plotted against cutting speed v (s = 0,058 mm/rev) when drilling blind holes 2,5D deep in KH18N10T steel with LZSOZHZ oil coolant using cemented-carbide and high-speed steel drills (D = 12mm) and against feed s (v = 42m/min).

1. ZHLUDOV, V. P., and MURZIN, F. E.

2. CEMENTED-CARBIDE DRILLS FOR DRILLING GLASS-FABRIC LAMINATE

3. MACHINES & TOOLING, Vol. 44, No. 1, 1973, pp. 41-42

4. Cemented-carbide drills were developed and tested for drilling holes of 0.95-6.1mm diameter and 1.5-2mm deep with and without chamfers in parts 1.5-2mm thick made of STEF - 2 glass-fabric laminate. Hole surface finish must be within Class 4 limits; negligible peeling of the top layer at entry and exit is permissible, and the burr must not exceed 0.1mm.

   These holes used to be drilled with R18 steel twist drills (lip clearance angle α = 11-14°, point angle 2ϕ = 60-70°, chisel edge angle ψ = 145°, helix angle ω = 35-50°, back taper 0.03mm per 100mm length) with hand feed and a cutting speed of 25m/min. R18 steel drills had a life not exceeding 150 holes. Chamfered holes were drilled in two passes: drilling, then chamfering with a large-diameter drill.

   The following cemented-carbide drills were developed: solid twist drills of D = 0.95-2.5mm diameter (Fig. 1(a)), composite twist drills of D = 2.6-6.1mm diameter (Fig. 1(b)) and combined monolithic drills of D = 2.3-3.6mm diameter (Fig. 1(c)). The 0.95-2.5mm diameter drills were made solid from rod blanks. The 2.6-6.1mm diameter drills were composite; the working part was made of cemented carbide, and this was pressed into a steel blank.

   To increase stiffness, the 0.95-2.5mm diameter drills had a core which widened towards the shank with a taper of 1°. The clearance faces of drills up to 4mm diameter had a single step (α = 20°), while those of drills above 4mm diameter had two steps (α = 20°, α_1 = 30°). Helix angle ω was 20-28° for 0.95-2.5mm diameter drills and 30-35° for 2.5-6.1mm diameter drills. The 2.6-6.1mm diameter drills had an undercut web, because the blanks had a thicker core. With a drilling depth of 2mm, the drill working section length was 7-10mm.

   A special fixture was designed and built for grinding the helical flutes (Fig. 2). The drill blank(rod) is clamped in collet 4. Depending on helix angle ω, one of tracers 2 is engaged. When handwheel 3 is rotated, spindle 1 is displaced axially by the tracer. The spiral flute is formed in the blank by the diamond wheel as a result of helical motion of the spindle.

   The drills were tested with cutting speed v = 50m/min and hand feed. It was found that cemented-carbide drills have a life of 1500 holes, i.e. 8-10 times greater than high-speed steel drills. Wear criterion was a clearance-face wear of ~0.2mm, because with greater wear the burrs become larger and there is considerable peeling at exit.

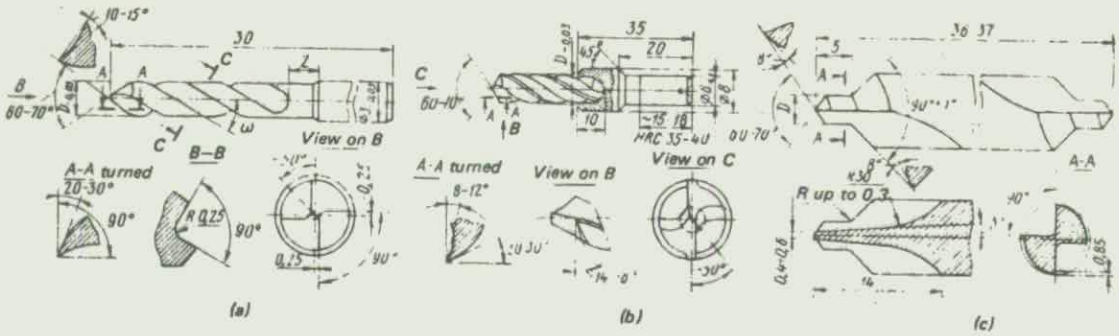

10-15°
30
B
60-70°
View on B
A-A turned
20-30°
90°
B-B
R 0.25
90°
0.25
35
20
45°
C
60-70°
10
HRC 35-40
View on B
View on C
A-A turned
8-12°
5
36 37
60-70°
A-A
R up to 0.3
90°
0.4-0.6
14
0.85
(a)
(b)
(c)

Fig. 1

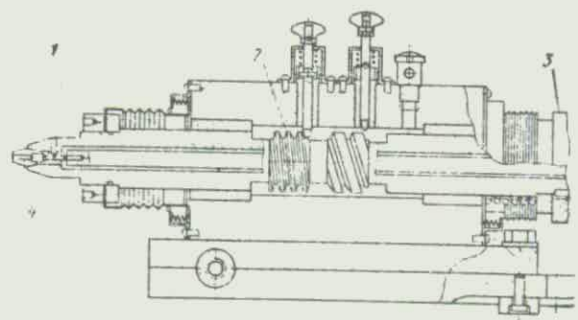

1
2
3
4

Fig. 2

1. LISHCHINSKII, L. YU and RABINOVICH, V. I.

2. OPTIMUM CONTROL OF CUTTING RATES IN DEEP-DRILLING MACHINES

3. MACHINES & TOOLING, Vol. 44, No. 3, 1973, pp. 28-31

4. The deep-drilling of small-diameter holes (up to 6mm) is usually done with twist drills. In the most general form the optimality criterion can be the specific metal-removal cost:

$$C_{sp} = \frac{a_1\left(1+\frac{t_{anc}}{t_p}\right) + k_t v}{q s_o n} \qquad (1)$$

where $k_t = (1/Wm_1)[a_1 t_{cm}(m_1+m_2) + a_2 t_r m_1 + b(1+m_2)]$ is the specific tool cost; a_1 is the operating cost of the basic machine per minute; a_2 is the same for the tool-grinding machine; t_p and t_{anc} are the cutting and ancillary displacement times; t_r and t_{cm} are the times for regrinding and changing the tool; m_1 and m_2 are the number of tool changes as a result of wear and fracture when machining a batch of components; b is the cost of the tool; q is the chip section; s_o is the feed rate per revolution; n is the spindle rotation speed; W is the permissible tool wear; v = W/T is the tool wear-rate; T is the tool life between regrinds.

An extreme value of the criterion is achieved by controlling cutting speed to suit the drilling depth. An optimum non-linear cutting-speed control law as a function of hole depth (determined in the preliminary investigations) can be approximated by sections of straight lines (Fig. 1) by dividing the entire speed regulation range into levels $v_1, v_2, \ldots, v_k$ corresponding to the passes. The length of each pass $\Delta \ell_i$ is determined by restrictions on maximum torque or minimum working feed.

The author goes on to describe an Automatic Program Regulation System (APRS) for use in controlling deep drilling machines. This system can command the withdrawal of the drill from the hole in three ways:

1. When the tool feedrate, s_m, reaches a set minimum value in all the passes.

2. When the feedrate decreases by a constant predetermined value $\Delta\ s_M$.

3. As with Method 2, but with a constant set length of first path.

Test results showed that controlling cutting rates, using an APRS, gives machining costs 3 times lower, with the same tool life.

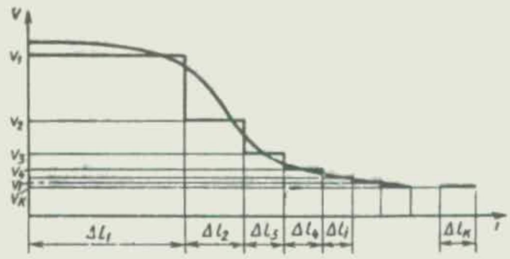


Fig. 1.
Approximation of optimum control law.

1. VINOGRADOV, A. A., et al

2. DESIGN OF CEMENTED-CARBIDE HEADS FOR COMPOSITE TWIST DRILLS

3. MACHINES AND TOOLING, Vol. 44, No. 6, 1973, pgs. 31-33

4. Optimum design parameters for c.c. heads and composite twist drills were determined for prototype twist drills with helical cemented-carbide heads. The tests were performed with heads of VK8 carbide of D = 12mm diameter and ℓ = 50 ± 0.5mm length with various design parameters.

Life tests involved drilling 30mm deep blind holes without coolant in 35KHGSA quench-hardened steel (HRC 50-52) in a vertical drilling machine. The asymmetrical cutting section of the drill had the following geometry: rake, clearance and side clearance angles in a plane normal to the cutting edge, $\gamma N = +6°$, $\alpha N = 15°$, $\alpha_s = 25°$; angles between lip and side cutting edges $2\phi = 130°$ and $2\phi_0 = 80°$; $\Delta\phi = 5°$; $\ell = 2.5$mm. Holes were drilled with v = 14.5m/min cutting speed and s = 0.058mm/rev feed. When wear at the corners reached 0.35-0.4mm and wear at the chisel edge reached 0.55-0.6mm, the drills were ground with synthetic diamond wheels in a universal tool-grinding machine.

Five measurements were made for each parameter. The results are shown in the Table. Probability intervals, i.e., the ranges in which mean values of life T are found with a probability of p = 0.95, were determined from the formula $\Delta = \pm tS/\sqrt{n}$, where t is the Student criterion, S the r.m.s. life deviation and n the number of tests. It will be seen from the Table that with a core diameter of d_c = 0.35D it is impossible to drill to a depth of 30mm without one or two withdrawals of the drill. With d_c = 0.42D it is necessary to withdraw the drill four or five times after drilling to a depth of 1.5D to prevent jamming of the drill as a result of swarf compaction. With d_c varying from 0.3D to 0.42D, drill life decreases by a factor of 2.3 as a result of the number of withdrawals increasing to five and the onset of vibration resulting from partial compaction of swarf. With d_c decreasing from 0.3D to 0.22D, drill life is reduced by 19.5% as a result of reduced stiffness.

The effect of ℓ_o on drill life was assessed with two values of v (14.5 and 21m/min) and s(0.038 and 0.058 mm/rev). Parameter ℓ_o was varied by varying the length of the spiral part of the drill and head. The test results are shown in Fig. 1, from which it will be seen that drill life T starts to decline rapidly with ℓ_o > 85mm. Thus, drill life with ℓ_o = 100mm (v = 21m/min) is approximately 45-54% lower than in the case of a drill with ℓ_o = 70mm. When drilling holes with lower cutting speeds (v = 14.5m/min) and with s = 0.058mm/rev, i.e., in conditions in which cutting speed increases, life is halved.

4. (Continued)

To determine the optimum value of d_c on the basis of drill strength, drilling tests were performed on KHN77TYUR creep-resisting alloy ($\sigma_t = 120kgf/mm^2$) with $\ell = 50$-$51mm$ and $\ell_o = 83$-$85mm$. A small hole depth was selected to avoid the introduction of new peak torque values resulting from swarf compaction with high feed rates. Cutting force was increased by varying feed rate, cutting speed and negative rake. Drills were tested with $d_c = 2.6$; 3.5; 4.1; $5.3mm$ and $\omega = 35^o$. Axial force P_o and torque M_t were measured with a dynamometer and strain gauges and recorded with a Type N105 oscillograph. Results of these tests are shown in Fig. 2. Varying d_c from 2.6 to 4.1mm increases M_t (Fig. 2(b)) and P_o (Fig. 2(a)) by 33 and 30% respectively. With $d_c = 0.44D$, drill fracture occurred only with a rake of $\gamma N = 15^o$; then $M_t = 584kgf.cm$, and $P_o = 2187kgf$. Drill fracture occurred mainly in the cemented carbide at the point of brazing, and sometimes also in the hardened steel shank.

The effect of parameter ω (flute helix angle) on drill strength was determined with drills having $d_c \approx 0.3D$. The test results are shown in Fig. 2, from which it will be seen that varying ω from 5° to 45° increases M_t by 33% and P_o corresponding to this M_t value by 27%. Although the most significant increase in M_t is observed with ω increasing from 35 to 45°, drill life is reduced. The optimum value of $\omega = 35°$ determined on the basis of maximum life should therefore be considered acceptable on the basis of drill strength.

Parameter investigated		$T \pm \Delta$, (min)	S, (min)	Drilling conditions
d_c/D	0,22	18,1±1,07	0,825	I
	0,30	22,5±1,35	1,09	I
	0,35	15,6±1,55	1,25	II
	0,42	9,8±1,04	0,835	IV
K	0	22,5±1,35	1,09	I
	1:100	20,0±0,766	0,616	II
	2:100	21,0±0,716	0,576	II
	3:100	18,6±0,285	0,229	III
ω (degrees)	5	13,3±1,45	1,17	V
	20	15,4±1,63	1,315	V
	35	22,5±1,35	1,09	I
	45	19,6±0,755	0,607	VI
l (mm)	8	17±0,312	0,126	I
	10	17,5±0,608	0,245	I
	17	18,7±0,712	0,287	I
	22,5	19,5±0,625	0,252	I
	35	20,0±0,536	0,216	I

Notes: 1. I – drilling to 30mm depth without drill withdrawal; II – same with one or two withdrawals; III – same with three withdrawals; IV – same with four or five withdrawals; V – drilling to 20mm depth without drill withdrawal; VI – drilling to 25mm depth without drill withdrawal.
2. Data obtained with $v = 14.5m/min$, $s = 0{,}058mm/rev$.
3. T and d_c/D relationship obtained with $K = 0$ and $\omega = 35°$; T and K relationship with $d_c/D = 0{,}3$ and $\omega = 35°$; T and ω relationship with $d_c/D = 0{,}3$ and $K = 0$.

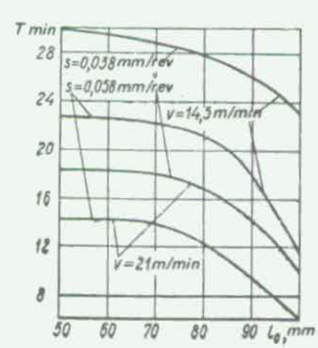


Fig. 1

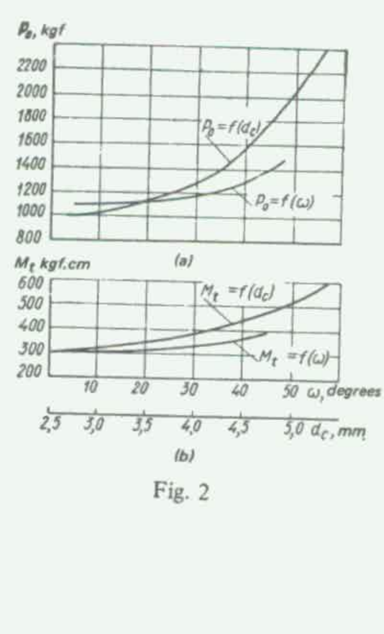


Fig. 2

1. SILIN, S. S.

2. TWO COMPONENT FERRITE-CORED INDUCTIVE SENSOR DYNAMOMETER FOR MEASURING DRILLING FORCES

3. MACHINES & TOOLING, Vol. 44, No. 8, 1973, pp. 49-50

4. The fundamental item in the design of the dynamometer (Fig. 1) is the tubular elastic quench-hardened unit 1 made of steel KhBG. Six horizontal apertures, arranged in two layers, have been ground from the upper part of this unit. The three upper apertures are displaced by 60° relative to the three lower apertures, with the result that the spaces between the apertures form six small elastic beams 4. During drilling these beams are bent by the action of the axial forces so that the table descends by an amount proportional to this force. Screw 5 is secured to the centre of the table. The ground end-face on the head of this screw acts on the moving unit 6 of the inductive sensor 7. The end-face of the screw must be located approximately in the centre of the plane in which the beams are located, although eccentric application of the axial and radial forces has no effect on the accuracy of the measurements.

Item 6 is a rod to which is attached a testolite core 8, which has ferrite cups 9 bonded to it. The body of the sensor unit 6 is suspended by means of two thin leaf springs (0.1 to 0.15mm thick), which produce the tension in the axial direction of the table. The body of the sensor is rigidly attached to the elastic item 1, to which stationary ferrite cups 11 are bonded to lugs on its internal surface. These cups are the locations for coils with 0.12mm diameter wire PEL (72 turns). The air gap between the surfaces of cups 9 and 11 is 0.3 to 0.5mm.

The sensor coils are connected to an electrical differential-network circuit. With the armature in the central position the inductive reactance of the sensor coils is equal, corresponding to its zero setting.

Four small vertical beams 3, arranged at equal intervals, are fitted to the lower part of the elastic element. These beams will bend on subjection to any torque. Ferrite discs which form the stationary unit in the torque sensor, are bonded to the lateral faces on the upper part of two of the small beams. The stationary elements 13 in this sensor are textolite rods of rectangular cross section with a 45° bevel on their end faces. Ferrite cups with coils, identical to coils 11, are bonded to the bevelled surfaces. The elastic element is secured to a textolite base 14 by an intermediate steel flange. This facilitates temperature measurement at the cutting zone by means of the natural thermocouple.

4. (Continued)

Figure 2 shows the electrical circuit for one of the metering channels of the dynamometer. The current required by each channel is not greater than 50mA. The dynamometer is sensitive to a torque of 100μA/kg.m, and to an axial force of 2μA/kg. The maximum measurable torque is 20kg.m and the maximum axial force 1200kg.

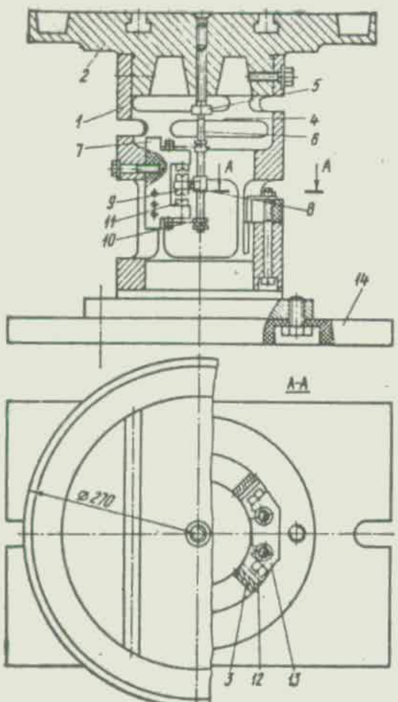


Fig. 1

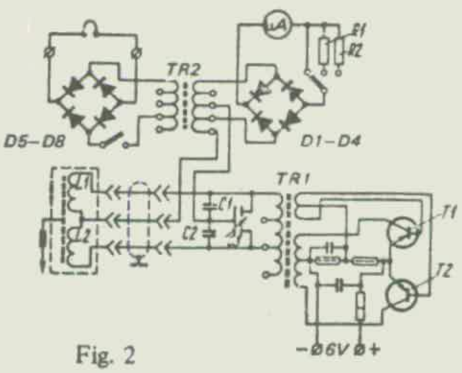


Fig. 2

1. KSENOFONTOV, YU. V. and STOLBOV, V. F.

2. PRODUCTION OF INTERNALLY-COOLED DRILLS

3. MACHINES AND TOOLING, Vol. 44, No. 8, 1973, pp. 50-52

4. A new method was developed and investigated for the production of drills with internal coolant-delivery channels. With this method, straight cast blanks of a suitable form with channels (Fig. 1) are subjected to plastic deformation (twisting) to form the spiral. The channels are produced in the casting by using straight cores or tubes which are located in the mould in the required position.

The blanks were cast in shell moulds. The sprues and inserts were made from a sodium silicate core mixture. To prevent formation of crust and to improve the surface finish of the castings, a special paint was used: a 20% spirit solution of phenolformaldehyde moulding powder brought up to a specific gravity of 1.55-1.6 by adding calcined quartz dust. Instead of being sprayed on the working part of the mould, as is usually done, the paint was sprayed on the hot pattern before application of the moulding mixture. This method of forming an anti-crusting coating guarantees constant casting dimensions, regardless of thickness.

The moulds were filled through the sprue system, which also located the tubes provided to form the coolant-channels. To select the best sprue system, five sprue inserts, as shown in Fig. 2(a)-2(e), were tried out. A sprue system with an insert of the type shown in Fig. 2(e) was found to be most successful in that it eliminated shrinkage and gas cavities and slag inclusions.

It was shown that quartz tubes are most suitable for forming internal channels in castings. 1Kh18N9T steel tubes melted, and the channels became blocked. Porcelain and ceramic tubes also proved unsuitable, because they fractured when the mould was filled with molten steel.

Tests showed that, even after pouring, plastic deformation and heat-treatment, quartz tubes do not fracture. When heated, they become softened and are easily deformed through the same angle as the drill blank, and the hole cross-section is unaltered. Upon heating for quenching and tempering in salt baths, the smooth inner surface of the quartz tube facilitates free circulation of the molten salts.

Both butt- and friction-welding of the drill working section and shank gave satisfactory results. It was found that welding can be done by conventional methods for high-speed and plain-carbon steels. After welding and annealing, the internal channels were joined by drilling at a distance of 10mm from

4. (Continued)

the weld; the connecting hole also served as the hole for attachment of the nipple.

A study of the cast drill blank-twisting process confirmed the previous investigations: at 1050-1100°C no cracks were observed on the sharp edges of the blanks. To relieve internal stresses and reduce hardness, the blanks were annealed by the normal method for high-speed steel.

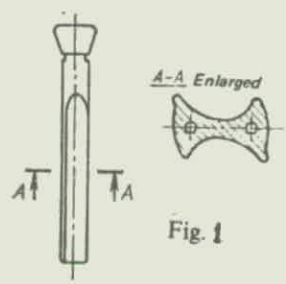


Fig. 1

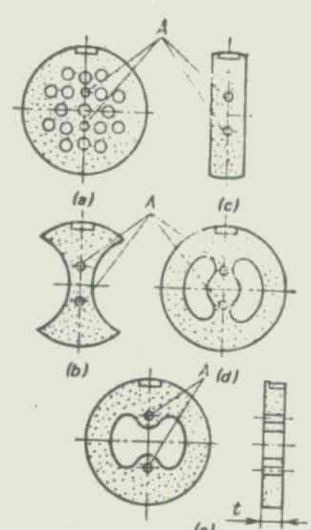


Fig. 2
A – holes for locating tubes.

1. SEREBRENITSKII, P. P., et al

2. DRILLS WITH MECHANICALLY-CLAMPED MULTI-EDGE CEMENTED-CARBIDE TIPS

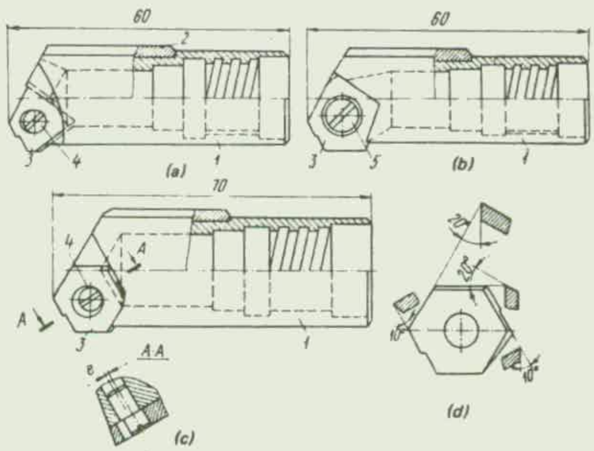
3. MACHINES AND TOOLING, Vol. 44, No. 9, 1973, p. 62

4. One-way drills with brazed cemented-carbide tips, which cannot be reground more than two or three times, are currently used for drilling deep holes up to 35mm diameter. A new drill design for drilling 19-32mm-diameter deep holes, with external coolant delivery and internal swarf removal, does not have this shortcoming. This type of drill uses standard throw-away multi-edge cemented-carbide tips which are mechanically attached.

   Body 1 (illustration (a)) and cemented-carbide guide key 2 are similar in design to conventional drill elements. The cutting part of the drill can be formed by a three-(a), five-(b) or six-sided (c) tip 3. Depending on its shape, the tip can be attached in various ways. A flat is made in the front part of body 1 for its attachment. Three- and six-sided tips are clamped with eccentric 4, and the five-sided tip with screw 5.

   Before assembly with the body the tips are ground and chamfered. For the five-sided tip, an additional chamfer is formed to take the screw head. The six-sided tip is made with two ground faces (d), so that two cutting edges can be used, whereas with the three- and five-sided tips only one edge is used.

   These drill designs were tested by drilling deep holes in heat-treated shafts (1600-1800mm long) in steels 18KHN3A, 40KH, 12KHN3A and 45 using a mixture of 75% sulphonated cutting oil and 25% paraffin as coolant. Drills tipped with T15K6 carbide operated stably at a cutting speed of 70-80m/min and a feed of 0.02-0.03mm/rev; removal rate was up to 2500-3000mm/h.



1. VYSOKOVSKII, E. S., et al

2. PREVENTATIVE TOOL-CHANGE INCREASES PRODUCTIVITY OF MULTI-SPINDLE DRILLING MACHINES

3. MACHINES & TOOLING, Vol. 44, No. 10, 1973, pgs. 16-17

4. It is known that tool life and cutting speed are connected by the expression

$$T = C_T/v^{\mu}, \tag{1}$$

where C_T and μ are constants.

It follows, from the formula, that each cutting speed v, all other things being equal, corresponds to a given value of life T. In actual operating conditions, however, because of a large number of factors connected with fluctuations in initial working conditions and the properties of the workpiece material, tool life is a random quantity obeying some distribution law. The formula permits mean life to be determined, but not less than 50% of all tools will require replacement before the given period.

Usually, the life scatter obeys the law shown in Fig. 1, which has three characteristic periods: $t_{g.o}$ is the guaranteed period, during which the tool operates without failure; t_{mod} is the most probable life period and T_o is the mean initial tool life. When the tool is changed after interval t_{mod}, tool failures can occur in the interval $t_{mod} > t > t_g$, but this gives minimum servicing and tool reconditioning costs. Period t_g is therefore optimum for preventative tool-change on the basis of dependability while period t_{mod} is the optimum period based on minimum operation cost. The closer the values of t_g and t_{mod} to the mean life, the greater the cutting speed (Fig. 2) and, consequently, the more effective preventative tool-change becomes.

Table 1 gives life variation factors v and preventative tool-change periods t_g for twist drills of 6.5 to 26mm diameter in various conditions. It will be seen from Table 1 that with centralized tool grinding and with stable geometrical parameters, coefficient v declines and quantity t_g approaches T.

The rise in productivity as a result of introducing preventative tool-change is illustrated for the example of an operation involving the drilling of 80 holes in two components. A comparative analysis of this operation with random and preventative tool-change in various cutting conditions and various values of v is illustrated in Fig. 2.

4. (Continued)

Preventative tool-change is even more effective when certain new tool steels are used. Table 2 shows the result of comparative tests in practical conditions with four batches of 13mm diameter twist drills (GOST 10903-64) in a Model 2135 machine. Four holes in components of 40G steel were drilled simultaneously. Here, $L = 26$mm, $\lambda = 0.615$, $s = 0.195$mm/rev, $v_o = 18.2$m/min. The drills were ground in non-centralized conditions. Analysis of the results shows that when drills of R18 steel are replaced by drills of R6M3 steel, mean life is increased by 90%, productivity by 3.5% and the variable part of the operation cost is reduced by 12.8%. With centralized grinding of the drills, the introduction of preventative replacement in these particular conditions increases productivity by 5.8% with a simultaneous reduction in the variable part of the operation cost by 17.8%.

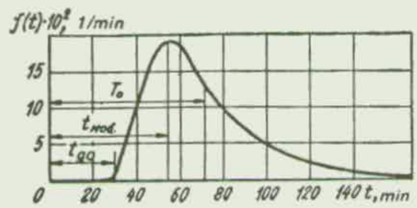


Fig. 1.
Life distribution of 6,5mm diameter drills with v_0 = 22,5m/min and s = 0,1mm/rev.

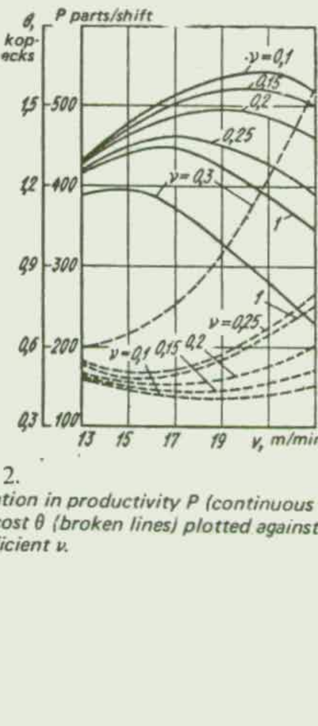


Fig. 2.
Variation in productivity P (continuous lines) and cost θ (broken lines) plotted against v and coefficient ν.

Table 1

Drill grinding method	ν	t_g
Non-centralized grinding without checking geometry	0,30–1,00	(0,18–0,5) T
Non-centralized grinding with partial checking of geometry	0,20–0,30	(0,5–0,6) T
Centralized grinding without checking of geometry	0,15–0,20	(0,60–0,75) T
Centralized grinding to ensure constant geometry	0,08–0,13	(0,75–0,90) T

Table 2

Grade of steel of drill	T_0 (min)	P components per shift	θ (kopecks)	ν
R18	57	860	0,314	0,52
R12	60	864	0,307	0,52
R6M3	107	890	0,274	0,48
R6M5	36	840	0.358	0,57

1. PETRUKHA, P. G., et al

2. DRILLING NIOBIUM ALLOYS

3. RUSSIAN ENGINEERING JOURNAL, Vol. 53, No. 11, 1973, pp. 73-74

4. The authors have investigated the drilling of grade 5VMTs Nb alloy (Nb 91.36%, W 5.1%, Mo 2.0%, Zr 1.1%, C 0.3%, O_2 0.12% and N 0.02%; tensile strength σ_V = 55 kgf/mm^2; elongation δ = 30%; reduction in area ψ = 70%; Vickers hardness 180 kgf/mm^2).

   In investigating the cutting properties of the tool material, 9 mm-diameter twist drills (R18, R9K5, R6M3 and R12F5M steels), and drills with brazed-on cutting edges VK8 alloy were used. The coolant was an aqueous solution of Coolant-8.

   It can be seen that R9K5 and R18 h.s.s. drills exhibit the best cutting properties; R6M3 drills exhibit a somewhat shorter life. Drills with brazed-on VK8 carbide inserts tend to break when drilling grade 5MMTs alloy under the same conditions (Fig. 1).

   In investigating the effect of the tool tip angle 2ϕ on drill life it was found that drills with 2ϕ = 125-130° had the maximum life.

   It follows from Fig. 2 that the drill life obtained on cooling with spindle oil is higher than in cooling with coolant-8.

   The Table shows the geometrical parameters and the results obtained in investigating the surface finish obtained in drilling, countersinking, and reaming holes in grade 5VMTs alloy using oleic acid as coolant.

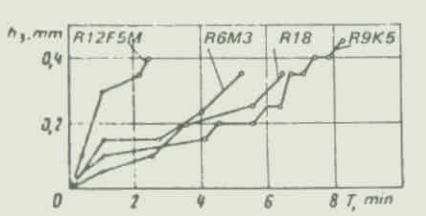


Fig. 1.
Wear h_3 on the clearance face of h.s.s. drills, as a function of cutting time T when drilling grade 5VMTs alloy (2ϕ = 120°; α = 10°), cutting speed v = 21m/min, feed s = 0,12mm per rev.

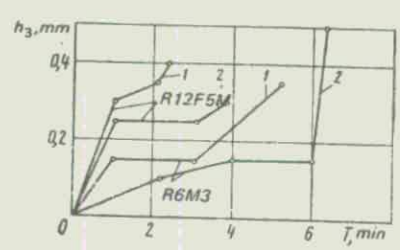


Fig. 2.
Effect of coolant on the life of twist drills when drilling grade 5VMTs alloy:
1 – cooling with coolant–8;
2 – cooling with spindle oil; (2ϕ = 120°, α = 10°), cutting speed v = 21m/min, feed s = 0,12mm per rev.

1. PROSSKOWITZ, A.

2. EINFLUSS DES KÜHLSCHMIERSTOFFES AUF STANDZEIT, ZERSPANKRAFT UND SPANBILDUNG BEIM BOHREN VON VERGÜTUNGSSTAHL (Effect of Coolant Materials on the Tool Life, Cutting Forces and Chip Curl Formation by Drilling in Tempered Steel)

3. INDUSTRIE-ANZEIGER, Vol. 95, No. 90-91, pp. 2071-2072, 1973

4. The effect of various coolant types on the tool life were reported in a number of publications.

   This report investigated the effect of various coolant types using coolant hole drilling. The volume of coolant in the coolant hole drill was varied. The main effects of the coolant volume were evaluated in terms of wearland in drill, torque, thrust and chip curl formation.

   The result of drill wear investigation is shown in Fig. 1.

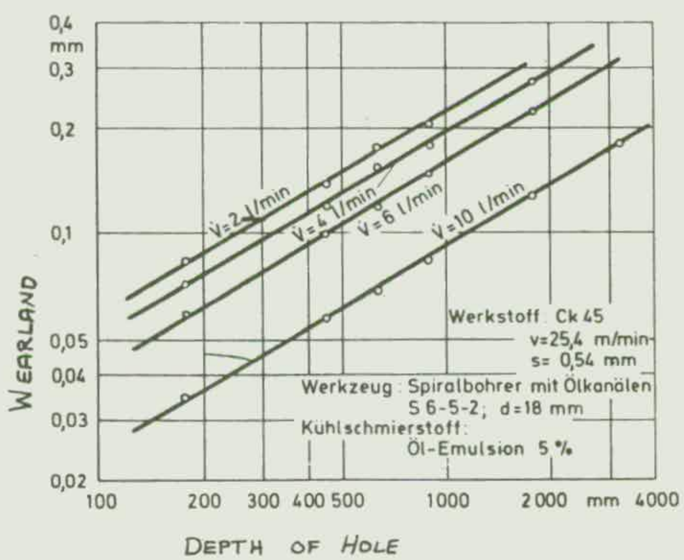


Fig. 1

1. ORTMANN, R.

2. ZERSPANUNGSVERSUCHE MIT BOHRWERKZEUGEN (Research on Metal Cutting with Twist Drill)

3. WERKSTATT UND BETRIEB, Vol. 106, No. 5, pp. 289-356, 1973

4. After turning, the drilling process is counted as the most frequently used metal cutting process, even though a clear and detailed knowledge on the operation of this process is not yet available. The reason for this may be due to the fact that the process is impossible to observe visually. In this paper, therefore, a couple of methods used for the investigation are presented, which will enable us to obtain an accurate knowledge of the problem. This knowledge may make it possible to explain the metal cutting process better. The results of the drill life investigation are presented in Fig. 1.

   The drill used was of the grade S6-5-2 type having an 8 mm diameter. The workpiece chosen was tool steel of C60W3, and the feed rate was 0.26 mm/rev. Total failure of the tool was used as the drill life criterion and this operation was conducted under dry conditions.

   As shown in Fig. 1, and using double logarithm coordinates, the drill life relationship with the drilling speeds, draws a straight line, which is also obtained in turning processes.

   The next investigation was conducted to determine the effect of drilling speed on drill wear measured at the flank face after a drilling length of 2000 mm and under various feed rates. Fig. 2 and Fig. 3 present the effect of feed rate on the drill wear under three drilling speeds.

   From these figures, it is indicated that the effect of feed rate would be more significant than that due to drilling speeds. This is especially noted when a large feed rate accelerates the drill wear exponentially. These facts can be explained by the appearance of built-up edge. As proof of this fact, the under side of drilled chips demonstrated different hardness in the particular zone when compared with the rest of the chips. By measurement of the magnitude of the chip root, the effect of drilling speeds and feed rate on the height of chip roots can be estimated.

   An interesting observation made was when the feed rate was reduced below 0.12 mm/rev. Using either drilling speeds, 11.7 m/min or 16.5 m/min, the height of the chip root curve followed parallel to that of the drill wear curve. (Fig. 4). However, higher feed rates than 0.26 mm/rev indicated no relationship between the height of chip root and drill wear.

4. (Continued)

The reason could be that higher feed rates exert extreme mechanical stresses on the drill edge, so that built-up edge has no chance to affect the drill wear (Fig. 5).

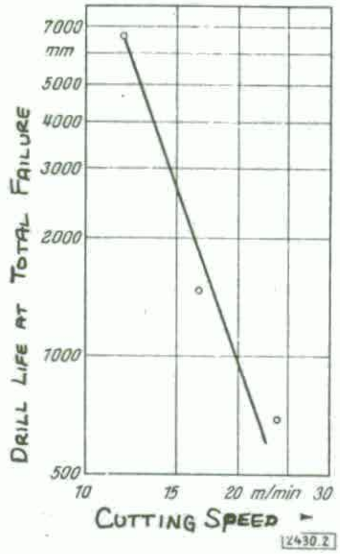
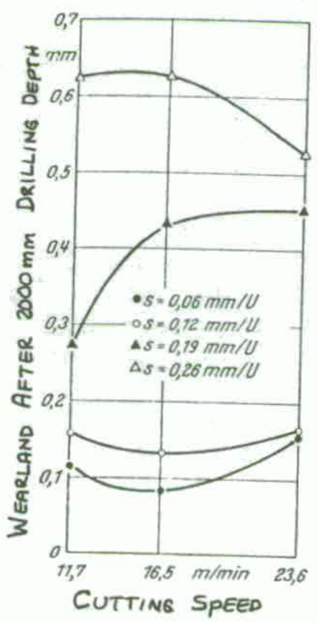


Fig. 1



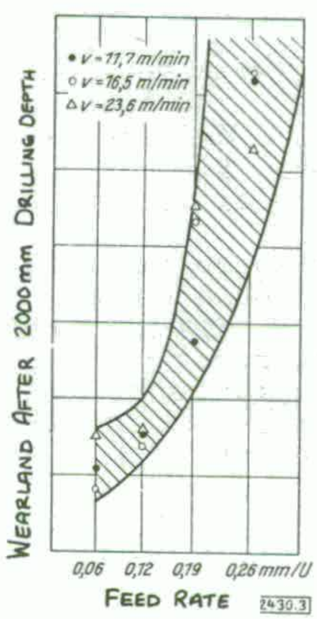


Fig. 2

Fig. 3

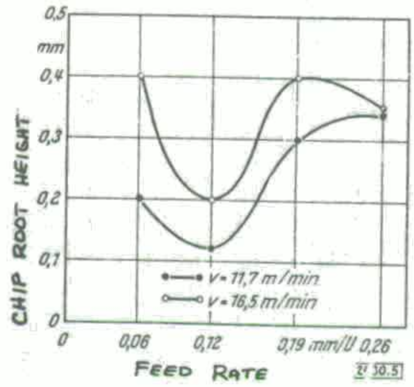
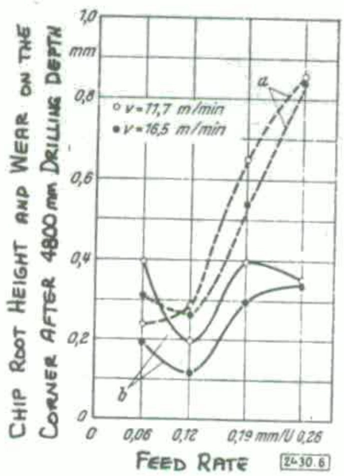


Fig. 4



a: WEARLAND

b: CHIP ROOT HEIGHT

Fig. 5

1. BHATTACHARYYA, A., CHATTERJEE, A. B., and MULLICK, B. K.

2. GEOMETRY AND PERFORMANCE OF MULTI-CONE AND CURVED-LIP TWIST DRILLS

3. ANNALS OF THE C.I.R.P., Vol. 22/1, pp. 27-28, 1973

4. The cutting speed in twist drills varies widely along the cutting edges giving non-uniform wear along the cutting edges resulting in reduction of over-all drill life. Therefore, any modification which would compensate partially or fully the uniform rise of the cutting speed by gradually decreasing the true feed along the cutting edges is expected to distribute the wear uniformly along the cutting edges and thus enhance the overall life of the drill.

In this paper the geometry of multi-cone, curved-lip and partially curved-lip drills have been analyzed and their geometrical parameters have been correlated with drilling forces and tool wear.

The simplest form of multi-cone drill is the double cone drill as shown in Fig. 1, where it is noted that the true feed is reduced at the periphery where the cutting speed is maximum.

From Fig. 1 it is seen that the effect of multi-coning of drills will be appreciable if the number of cones are increased, in the extreme case this reduces to the form of curved-lip drill shown in Fig. 2.

The nature of variation of effective rake angle for a double cone drill, a curved-lip drill and a partially curved-lip drill is shown in Fig. 3 which indicates that by modification of the drill point the overall effective rake angle does not decrease but is improved particularly at the crucial point like chisel edge.

A relationship for the tool-life criterion Φ with respect to variation in principal cutting edge angle Φ_i is obtained in the form,

$$\Phi = \frac{r_i}{r}^{-y} (\sin\Phi_i)^{-z}$$

Using the experimental values of inserts for a particular case, when $y = 2.0$ and $z = 1.5$, four curves have been drawn on semi-log paper for different designs of drills to show the variation of Φ along the cutting edge as shown in Fig. 4. It is noted that tool life improves remarkably by such drilling point modification.

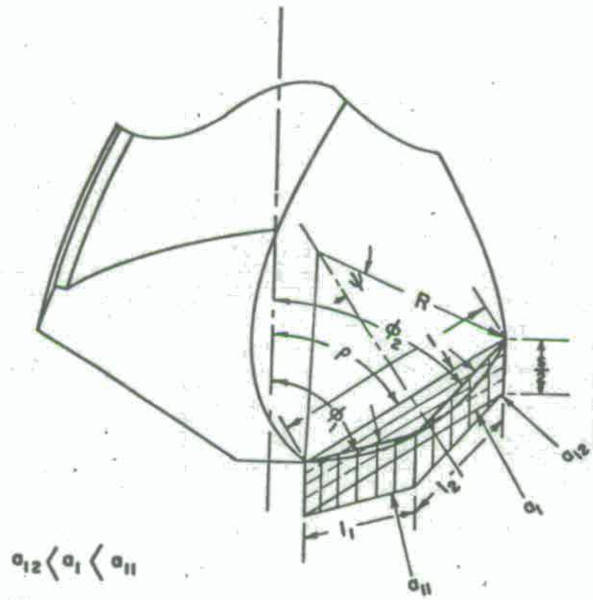


Fig. 1. Double-cone drill

Fig. 1

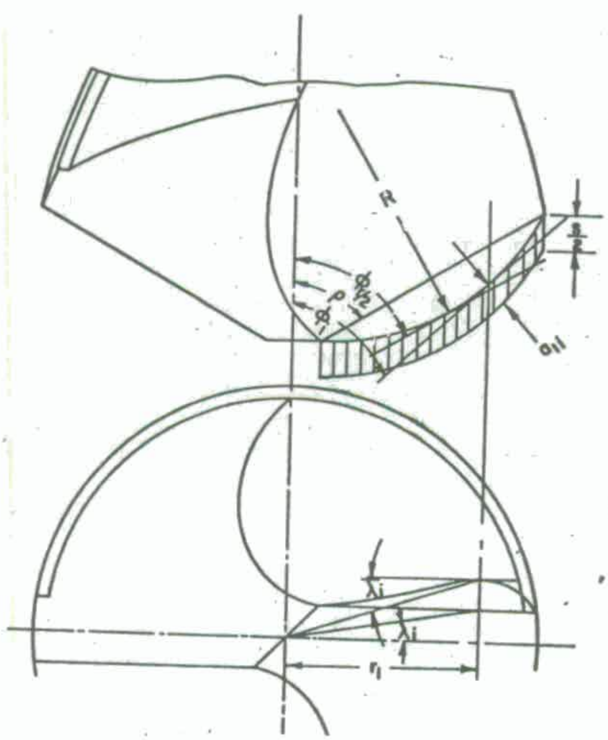


Fig. 2

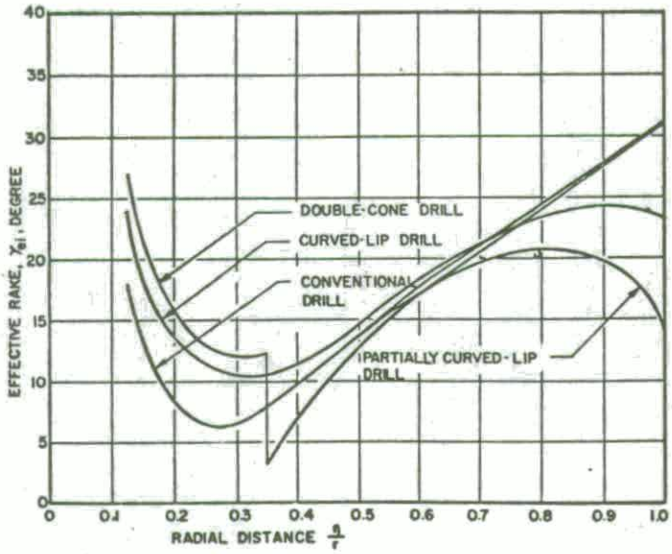


Fig. 3. Effective rake of various designs of drills

Fig. 3

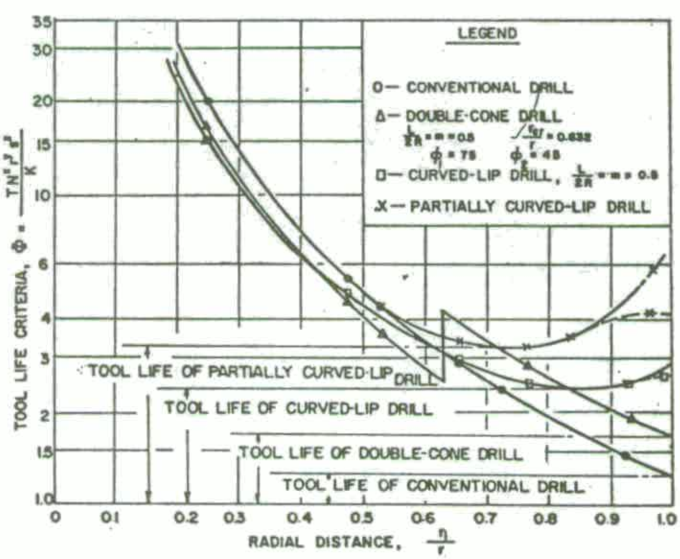


Fig. 4. Effect of different drill point modification on the life of drills

Fig. 4

1. WILLIAMS, R. A.

2. A STUDY OF THE DRILLING PROCESSES

3. TRANSACTIONS OF THE ASME, JOURNAL OF ENGINEERING FOR INDUSTRY, Series B, Nov. 1974, pp. 1207-1215

4. The cutting action of the twist drill is centered round the drill point where the main cutting edges, Fig. 1(a), are 180 deg out of phase and are joined across the drill web by the chisel edge. The geometry across the cutting edges of the drill point is an involved function of point angle, 2k, the helix angle, v, and the web thickness, 2t and, to further complicate subsequent analysis, the rotational velocity of the drill (or work) varies from the drill center to the outer corner.

The experimental investigation by Oxford Jnr. showed that during cutting there were three identifiable zones of interest at the drill point, namely, the main cutting edges (or lips), the secondary cutting edges at the chisel edge, and an indentation zone about the drill center, Fig. 1(b). It is therefore reasonable to assume that at least three models would be needed to simulate the whole drilling process; of these, two would be models of chip formation and one an indentation model.

Two drills of 0.625 in. diameter, one with a point angle of 110 degrees and one with an angle of 130 degrees, were used to drill K1045 steel. Five holes, 1 in. deep, were drilled in 1 in. diameter x 2.5 in. long specimens at a constant speed of 54 fpm at each of five feed levels: 3, 5, 7, 9, and 12 x 10^{-3} ipr. In each test, random selection of feed rate was used, and the drills were resharpened between each reapplication of feed rate. From these results, theoretical values of torque and thrust were derived.

Experimental results were obtained by tests using .0625 in. diameter drills with point angles of 115, 120, and 125 degrees. Each drill again drilled five holes, at the previous feed levels and cutting speed. The mean values of torque and thrust obtained in these tests were compared with the theoretical results.

Although the predicted levels of total torque and thrust were in good agreement with actual values, the estimated contributions to each force by the various regions at the drill point was not consistent with that expected in practice. There is evidence to suggest that the main cutting edge contributes approximately 85 percent of the total torque and approximately 40 percent of the total thrust developed by a drill. An analysis of the data in Table 1 shows that from this theoretical study, the chisel edge makes a negligible contribution to the

4. (Continued)

total torque while the main cutting edge appears to account for about 60 percent of the total thrust. This anomaly could be due to an overestimate in the level of k_L and the corresponding underestimate of k_c.

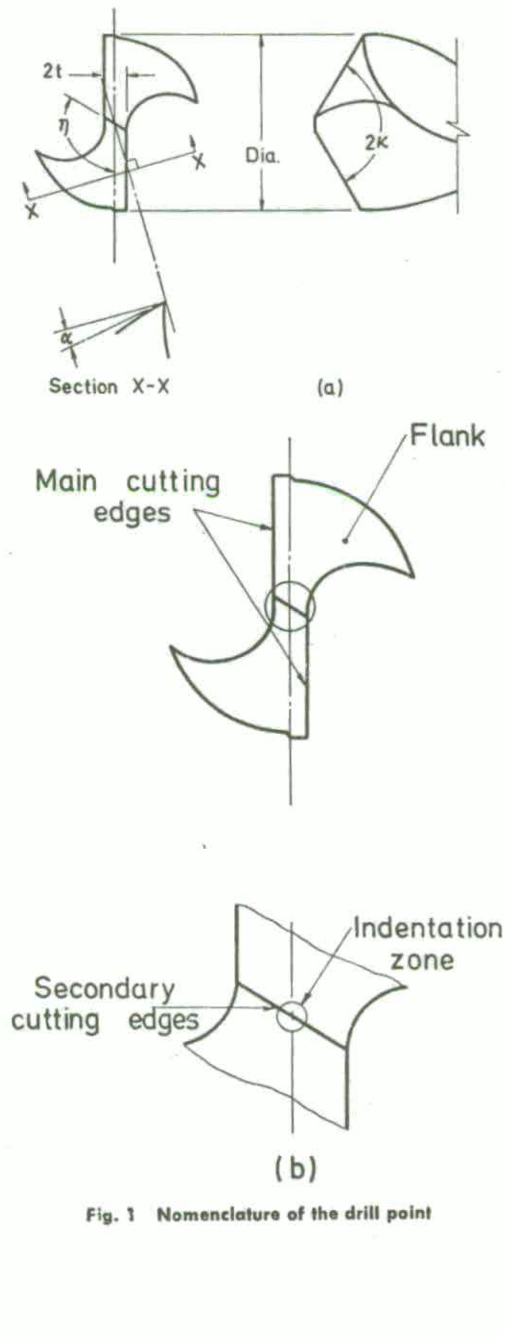


Fig. 1 Nomenclature of the drill point

1. ANONYMOUS

2. PUT THE MECHANICS OF DRILLING TO WORK

3. MACHINE AND TOOL BLUE BOOK, April 1974, pp. 89-95

4. Use these hints to complement properly applied mechanics:

    1. Always examine a drill point before use.
    2. Set correct rpm.
    3. Do not allow drill to penetrate through workpiece into hard surfaces (table, vise, etc.)
    4. Clamp work securely.
    5. Keep end of workpiece farthest from hole to the left.
    6. Be sure shank, sleeve and machine spindle are clean.
    7. Start each hole with a center drill.
    8. Clamp thin workpieces to a hardwood block for drilling.

    Chip Formation

    Because of the limited chip room in a drill, it is always desirable to have the chips broken up into relatively small pieces. Coiling of drill chips, while spectacular in appearance, must be avoided, especially if the hole is of any considerable depth. These coils tend to pack up in the flutes and to stop succeeding chips from coming out. In turn, this stops the flow of coolant to the cutting edges. Excessive heat and premature dulling will invariably result.

    The two main factors that affect chip formation are:

    1. The ductility of the material to be drilled.
    2. The thickness of chip, or feed per revolution.

    When drilling ductile material, the chips tend to bend and coil up as they are being separated from the work. In less ductile materials the chips will tend to break up into pieces rather than coil. This latter is the desirable condition, and usually such materials can be drilled with the standard type of twist drills without any alternations.

    When drilling the more ductile materials, it is sometimes necessary to go to rather extraordinary lengths to attain the proper breaking up of the chips so that they can be readily ejected.

    The most common method is to decrease the rake angles of the cutting lips. As these angles are decreased, the effect is to cause the chips to bend more sharply. This usually will cause them to break, unless the material is extremely ductile. The amount of decrease of the rake angles can be varied to suit the material to be drilled.

4. (Continued)

The rake angles must not be negative, as this will materially reduce the efficiency and life of the drill.

The clogging of drill flutes by coiled chips can often be remedied by increasing the feed per revolution; in other words, by increasing the thickness of the chips. Naturally this can only be done within the practical limits of the structural strength of the drill. Inasmuch as the average drilling setup tends toward high speeds and low feeds, it is always advisable to look into this when trouble with coiling chips is encountered.

Chatter

To those having experience with the cutting of metals, "chatter" is a familiar phenomenon. It can be defined as synchronized vibrations that are set up in the cutting tool, the work, the machine, or a combination of vibrations in all of these elements.

The cause of these vibrations or chatter, usually is found in a lack of rigidity. This lack of rigidity permits the affected members to deflect under the cutting strains until the load builds up to a point where the material to be cut gives way. As the material is ruptured, the strains are lessened, and the deflected member springs back to its natural position; but the resistance begins to build up again at once, causing another deflection. This process, when rapidly repeated, sets up vibrations that we know as chatter.

The effect is a hammering action of the cutting edge or edges against the work. This hammering may cause the cutting edges to chip out in small pieces, or it may cause the body of the tool to fracture. Deflections, continued over a period of time, may also cause failure of the tool or of the machine by fatigue.

If the hole to be drilled equals or exceeds three times the diameter of the drill, the operation falls in the deep-hole-drilling class, and some adjustment of feeds and speeds is necessary in order to secure maximum efficiency. In considering the depth of the hole, the effect of bushings must be taken into account. A drill bushing set very close to the work becomes in effect an extension of the hole itself, and on holes from two to three diameters deep complicates the problem of chip disposal.

In its final analysis it is entirely a matter of conducting away the heat generated. It is a fact that if less heat is conducted away than is generated, the drill will eventually overheat and be destroyed.

4. (Continued)

While the nature and amount of coolant applied to a given drilling operation will affect the depth of hole that can safely be drilled at ordinary feeds and speeds, the depth of three diameters is a good point at which to begin the stepping-down. This applies particularly to speed.

The following table will serve as a guide to the proper reductions as the depth of the hole increases:

Depth of Hole	Reduction of Speed, Percent
3 times drill diameter	10
4 times drill diameter	20
5 times drill diameter	30
6-8 times drill diameter	35-40

Depth of Hole	Reduction of Feed, Percent
3-4 times drill diameter	10
5-8 times drill diameter	20

If excellent cooling conditions are present, the above rates may be increased; but if there is little or no provision for cooling, it may be necessary to step down even lower than the figures given.

1. ANONYMOUS

2. A COMMON SENSE APPROACH TO SELECTING AND USING CUTTING FLUIDS FOR DRILLING

3. MACHINE AND TOOL BLUE BOOK, May 1974, pp. 108-112

4. Correct selection and application of cutting fluids for drilling as for most metal cutting operations, is essential. Their use results in (1) reducing tool wear so they last longer and less time is spent resharpening and resetting; (2) speeding production due to reduced heat and friction and the use of higher cutting speeds; (3) lessening labor cost by reducing the number of production stoppages for such things as tool resharpening; and (4) lowering power costs by reducing friction.

Chip Disposal

Usually the chip breaker will take a form similar to that shown in Fig. 1. The proportions shown are subject to wide variations and must be worked out for each job.

Occasionally, it is advisable to split the chips lengthwise. This can be accomplished by the type of breaker shown in Fig. 2. These grooves should be spaced alternately, so that grooves in opposite flutes are not equidistant from the axis of the drill. Such grooves should be made with a wheel dressed to a radius to avoid localization of stresses in any sharp corners.

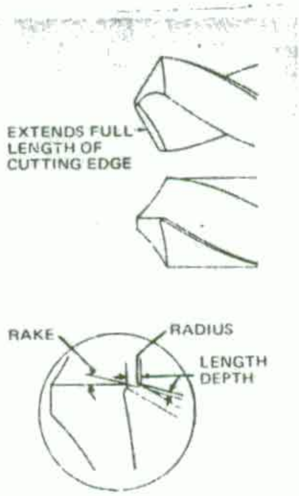


Fig. 1

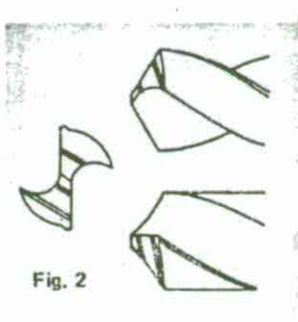


Fig. 2

1. VINOGRADOV, A. A. and ANOSOV, Yu. L.

2. ASYMMETRICALLY GROUND H.S.S. DRILLS

3. MACHINES AND TOOLING, Vol. 45, No. 1, 1974, pp. 39-41

4. Experiments were performed in which standard twist drills made of R18 steel with a symmetrical standard point were compared in performance with nonstandard drills with asymmetrically ground points. Asymmetric points can be obtained by, for example, lowering one lip over its entire length during grinding with respect to the other lip. It was found earlier that asymmetrically ground carbide drills had longer life and produced more accurate holes with better surface finish.

This article presents the results of tool life tests obtained in drilling high manganese steels MML-1, MML-2 and 45G17Yu3Kh using drills with symmetrical and asymmetric points; the geometry of the cutting parts is shown in Fig. 1. To produce accurate symmetry of the cutting edges in one kind of drill and ensure best conditions for revealing the effect of asymmetric grinding on the life in the other, the drills were ground on both rake and flank surfaces. The asymmetry of the cutting part was attained by additional grinding of the flank of one lobe. This increased the drill point angle by $\Delta\phi = 3°$. Part of the cutting edge (lip) equal to 0.18D was not additionally ground and remained symmetrical to the other edge.

Drills were tested in producing blind holes of 2.5D depth on vertical drill Model 2A150, provided with an additional planetary speed reducer in its gearbox which reduced the feed rates by a factor of 10.75. Drills of 16.5mm diameter were used when drilling steel 45G17Yu3Kh, and drills 20.75mm when drilling steels MML-1 and MML-2.

Cooling was provided by a 5% water emulsion of ET-1 oil at a flow rate of 10ℓ/minute. Tool wear was measured with a MPB-2 microscope, and hole enlargement with an indicator type depth gauge reading 0.01mm per division. Bluntness was determined by the occurrence of the characteristic screech. It was found that the wear on the different parts of the cutting edges of drills with symmetrical and asymmetric grinding was not equal. Wear distribution on the flank surfaces is shown schematically in Fig. 2, where h_n and h_y are the wear respectively of the chisel edge and the corner.

Table 1 presents drill chisel edge and corner wear corresponding to the bluntness criterion. The parameter which defines drill life with symmetrical point when drilling steels MML-1 and MML-2 is chisel edge wear of approximately 1mm. Corner wear which does not exceed 0.15-0.2mm during almost the entire life period, drastically increases at that instant

4. (Continued)

at which vibrations occur which accompany the screech. Drills with asymmetric grinding exhibit primarily corner wear, namely of that corner whose lip was additionally ground. Magnitude of this wear determines drill life. Chisel wear in these drills is significantly smaller than in symmetrically ground drills.

Hole enlargement at the beginning and the end of the life period (Table 2) produced by asymmetrical drills is significantly (1.5-2.5 times) greater than with symmetrical. The enlargement is not uniform during the entire life period.

Life of asymmetrical drills (Fig. 3) is twice higher than that of symmetrical drills when drilling steel 45G17Yu3Kh and respectively 2.5 and more than 3 times higher when drilling steels MML-1 and MML-2. Drills in which the asymmetry is obtained by lowering one cutting edge with respect to the other, plan view angles being the same or different, have a life 1.5 times longer than symmetrically ground drills, but as a rule produce lobed holes.

Table 1.

Steel	Wear (mm)			
	chisel edge		corners	
	symmetric	asymmetric	symmetric	asymmetric
MML-1	1,00±0,10	0,70±0,10	0,25±0.15	0,40±0,10
MML-2	1,10±0,20	0,75±0,15	0,55±0,15	0,60±0,10
45G17Yu3Kh	0,25±0,05	0,25±0,05	0,40±0,10	0,70±0,20

Note: Averages of 8-10 measurements

Table 2.

Steel	Hole enlargement (in mm) during drill life			
	symmetric		asymmetric	
	At the beginning of life period	At the end of life period	At the beginning of life period	At the end of life period
MML-1	0,13±0.04	0.04±0.03	0,30±0.10	0,11±0,05
MML-2	0.24±0.10	0,04±0,03	0.37±0.10	0,14±0,05
45G17Yu3Kh	0,18±0,04	0,05±0,03	0,41±0.10	0,18±0,05

Note: Averages of 8-10 measurements

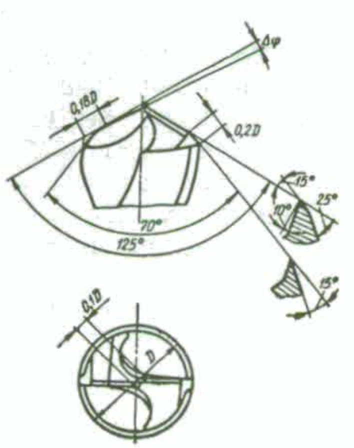


Fig. 1.
Asymmetrically ground drill part.

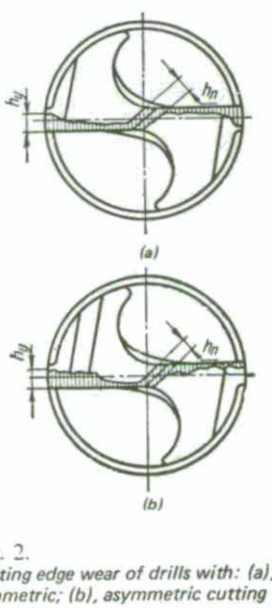


Fig. 2.
Cutting edge wear of drills with: (a), symmetric; (b), asymmetric cutting end.

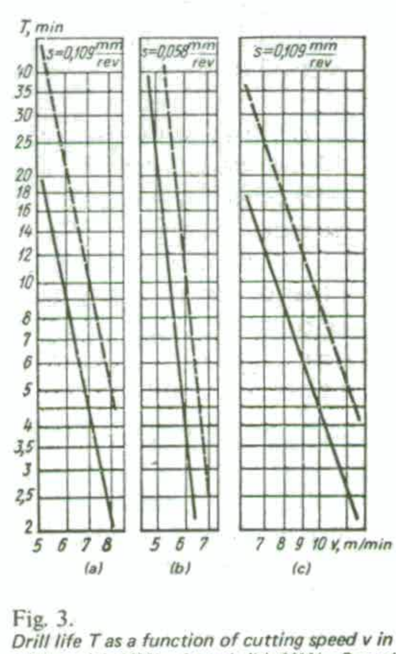


Fig. 3.
Drill life T as a function of cutting speed v in drilling: (a), MML–1 steel; (b), MML–2 steel; (c), 45G17Yu3Kh steel; dotted line represents the asymmetric drill.

1. ZHILIS, V. I. and VASENIS, G. A.

2. HOW DRILL LENGTH AND PRODUCTION TECHNOLOGY AFFECT TOOL LIFE AND HOLE ACCURACY

3. MACHINES AND TOOLING, Vol. 45, No. 2, 1974, pp. 40-42

4. More than 175,000 holes were drilled in the life tests. Figure 1 shows the variation in life T of drills tested with $v = 32.9$ m/min (a and b) and $s = 0.17$ mm/rev (c and d) to maximum wear (a and c) and to $h_{cl} = 0.39$ mm (b and d). Here curves 1 correspond to short drills, curves 2 to medium drills and curves 3 to long drills; broken lines relate to milled drills and continuous lines to ground drills. As a result of mathematical analysis of the life test results it was possible to rewrite the known formula for evaluating drill life in more accurate form.

Figure 2 shows the variation in drill wear h_{cl} (with ground flutes) plotted against drilling rates (I-V): rate I corresponds to a feed of 131 mm/min, II to 159 mm/min, III to 223 mm/min, IV to 279 mm/min and V to 288 mm/min. It will be noted that wear h_{cl} depends on the feed per minute: the greater this feed, the more rapid the clearance-face wear.

To investigate the effect of drill length and production technology on drilled hole quality, holes of 8 mm diameter were drilled in sandwich blanks in a Model 2A450 jig-boring machine. After drilling, the triple-layer blanks were dismantled and the hole displacement and diameter were gauged through the entire hole depth. Maximum coordinate read-off error was 0.002 mm, and drill land eccentricity at setting-up did not exceed 0.05 mm. Figure 3(a) shows the results of tests with $s = 0.16$ mm/rev using 80 mm long drills (curves 1), 115 mm long (curves 2) and 165 mm long (curves 3), while Fig. 3(b) shows results with 165 mm long drills with a hole depth of $h = 1$ mm (curves 4), $h = 25$ mm (curves 5) and $h = 41$ mm (curves 6).

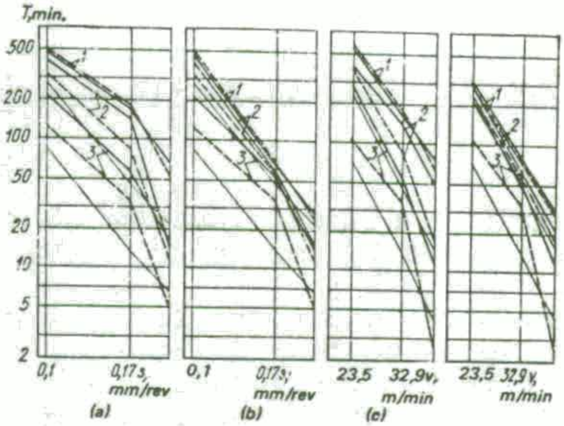


Fig. 1.
Effect of drill production technology and length on life: upper fine lines—life calculated from NIBTN standards[1], lower fine lines—TSBPNT standards[2].

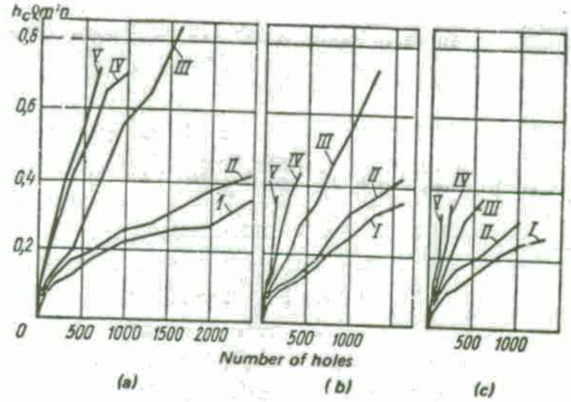


Fig. 2.
Clearance-face wear h_{c1} of ground drills to GOST 4010–64 (a), GOST 10902–64 (b), GOST 886–64 (c), related to number of holes drilled; I–V—drilling rates.

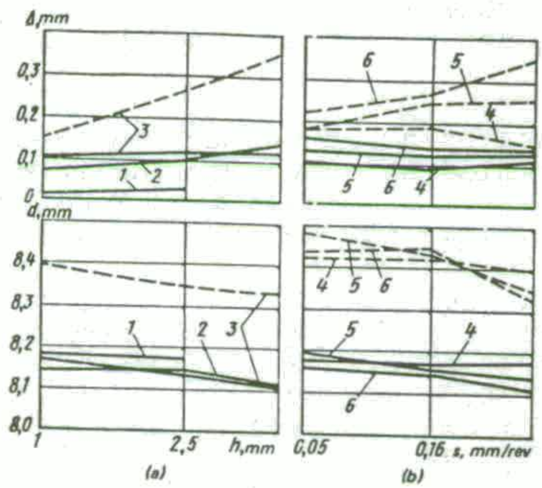


Fig. 3.
Axial displacement Δ and diametral increase d of hole plotted against drilling depth h (a), and feed rate s (b), with v = 27,7m/min; continuous and broken lines—as in Fig. 1.

1. BALKOV, V. P.

2. TWIST DRILLS FOR NC MACHINE TOOLS

3. MACHINES AND TOOLING, Vol. 45, No. 3, 1974, pp. 16-17

4. Experiments were conducted to establish requirements for drills used for drilling Class 4 accuracy holes with hole-positioning accuracy of 0.15mm, i.e., in conditions often encountered when machining body type components.

The effect of drill-point geometry, radial throw, displacement of chisel-edge and shank accuracy on the drilling accuracy was established. Holes were drilled in 45 steel (HB220) on a jig borer using cylindrical shank drills (R18 steel) of 10.5mm-diameter.

The point geometry of drills working without centering should ensure good centering at the start. This can be achieved by producing a convex chisel-edge and making its cutting rake less negative (Fig. 1). Ordinary drill pointing methods produce a very slight chisel-edge convexity approximately equal to (0.002-0.02)d, and large negative cutting rakes. Special drill pointing methods permit to increase chisel-edge convexity to (0.03-0.05)d and improve its geometry.

The Table gives experimental results comparing the accuracy of holes produced with drills ground by various methods. As shown in the Table, drills with a conventional helical flank (relief) surface and slight chisel-edge convexity do not produce satisfactory accuracy. Best results are obtained with drills with a helical flank surface and increased chisel-edge convexity. Satisfactory results were also obtained with drills with a two-plane flank surface and point-thinning, which make the chisel-edge cutting rake less negative. Similar experiments in drilling cast-iron (HB180) confirmed the dependence of hole accuracy upon drill-point geometry. Figure 2 shows experimental results of the effect of drill-point radial throw and chisel-edge displacement on hole position accuracy. Tested were drills with helical flank surface and convex chisel-edge (spiral point) [f = (0.04-0.045)d] (solid lines) and regular point drills (dotted line). As seen in the diagram, with increasing chisel-edge displacement and drill-point throw the hole-axis position accuracy drastically reduces.

Drill flank (relief) surface form	Hole-axis displacement (mm)				Hole-bellmouthing (mm)			
	At entry		At exit		At entry		At exit	
	$\overline{X}$	s	$\overline{X}$	s	$\overline{X}$	s	$\overline{X}$	s
Two-plane; $\psi = 56°$; $\gamma = 57°$; $f = 0{,}28$mm	0,087	0,039	0,090	0,033	0,11	0,045	0,08	0,027
Two-plane with point thinning; $\psi = 56°$; $\gamma = -5°$; $f = 0{,}22$mm	0,063	0,030	0,062	0,025	0,12	0,022	0,10	0,011
Helical; $\psi = 55°$; γ–variable; $f = 0{,}025$mm	0,171	0,027	0,064	0,035	0,20	0,027	0,16	0,032
Helical; $\psi = 57°$; γ–variable; $f = 0{,}45$mm	0,040	0,020	0,043	0,024	0,10	0,025	0,09	0,017

Remark: ψ is the chisel-edge inclination angle; f is the chisel-edge convexity; γ is the chisel-edge cutting rake.

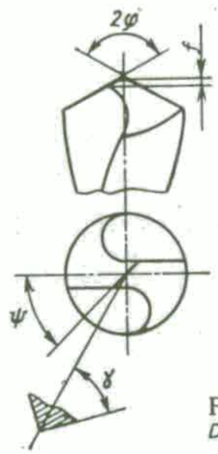


Fig. 1.
Drill-point geometry.

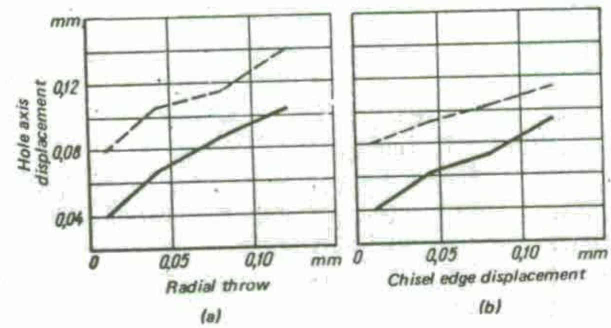


Fig. 2.
Hole-position accuracy depending upon drill end radial throw (a), and chisel-edge displacement (b).

1. SINEL'SHCHIKOV, A. K., and FILIPPOV, G. V.

2. MORE EFFECTIVE DRILLING WITH TWIST DRILLS

3. MACHINES AND TOOLING, Vol. 45, No. 3, 1974, pp. 56-58

4. When deep holes (with a length (ℓ) to diameter (d) ratio between 3-7) are drilled with flood delivery of the coolant, difficulties arise because the fluid penetrates to a depth of ~(2.5-3)d, after which its penetrating capacity declines sharply because of the swarf moving in the opposite direction. This leads to a temperature rise in the cutting-zone, increased chip-rake contact length, a change in the nature of the swarf, impaired swarf removal conditions, intensive adherence of the workpiece material to the lands, and rapid tool wear. In addition, packing of the swarf leads to a rise in axial force and torque (Fig. 1); torque rises especially rapidly. Deep holes are therefore drilled as a rule with intermediate withdrawal of the drill and at reduced cutting rates (10-40% lower, depending on ℓ/d).

For effective drilling of (3-7)d deep holes without intermediate withdrawal it is possible to recommend drills with coolant-delivery channels, which give good productivity and tool life (Fig. 2). These recommendations are confirmed by practical experience gained in the USSR and abroad. In particular, life tests on 12mm-diameter drills showed that if coolant is delivered through the drill channels at a constant pressure p $\approx$3kgf/cm^2, tool life is much greater (Table 1) than when the fluid is flood delivered. At the same time, the cutting properties of the drill are more stable.

Analysis of research data shows that although the advantages of fluid delivery via channels in the drill compared with flood delivery are widely recognized, differences of opinion remain as to optimum pressure and method of delivering the fluid to the channels, etc. The opinion that twist-drills with coolant-delivery channels will not find wide application because of their lower strength, and the need for special devices to deliver the fluid at extremely high pressure, is unjustified and not confirmed by practical experience with these drills.

Table 1

Drill design	l/d	Mean life at end of test: Number of holes	Mean life at end of test: min	Mean life (with land wear of h_1=1,1mm) in min
Standard	2,5	548	105	80
	4	97	29	19,5
With chip-breaker grooves	2,5	587	111,5	86
	4	231	67,9	54
	6	92	39,6	12,1
NPIL	2,5	438	84	74
	4	322	97	80
	6	156	68,8	20,5
With coolant-delivery channels	4	761	230	216
	6	351	154,5	123

Note. Data obtained in the drilling of steel 45 (HB 207) with a 5–6% emulsion coolant; d=14,5mm; v=33,4m/min; s=0,28mm/rev; l_0 = 115mm.

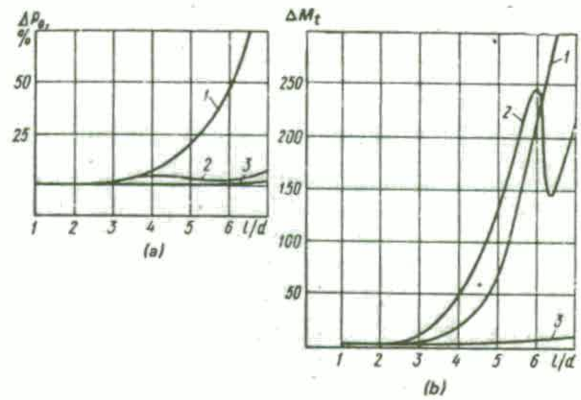


Fig. 1.

Variation in axial force ΔP_0 (a), and torque ΔM_t, (b), plotted against drilling length (d = 14,5mm, v = 16m/min, s = 0,28mm/rev; workpiece material steel 45, HB 197; working-section length ℓ_0 = 189mm):
1 – Standard drills;
2 – NPIL drills;
3 – drills with coolant-delivery channels.

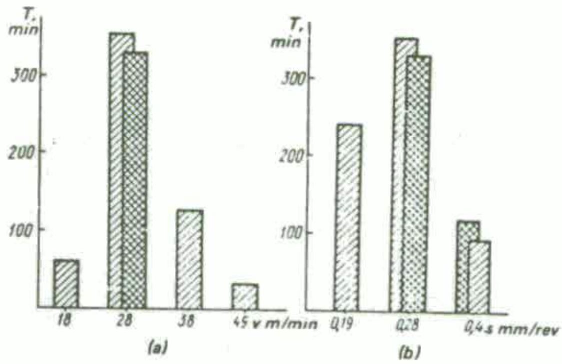


Fig. 2.
Drill (with coolant-delivery channels) life T plotted against cutting speed (a), with s = 0,28mm/rev and against feed, (b), with v = 28m/min (d = 12mm, ℓ = 4d; workpiece material steel 45; HB 197; coolant 5–6% emulsion; p = 3–4kgf/cm^2); single hatching–drills with central channel; cross hatching–drills with round channels in teeth.

1. RYABOV, A. V.

2. DESIGN OF SWARF COLLECTORS FOR DRILLS

3. MACHINES AND TOOLING, Vol. 45, No. 5, 1974, pp. 32-33

4. Dust-type swarf collectors for drilling machines are made of sheet steel in the form of a rectangular duct of width b and height h. At one end the swarf collector is connected to the suction pipe of a pneumatic transport system and at the other end has a slot for air entry. Holes for drill passage are provided in the wide section of the duct.

The economics and effectiveness of swarf removal are determined by the parameters b and h. Methodology is presented for calculating the optimum dimensions b and h satisfying the condition of minimum power required for swarf removal.

The value of P depends only upon the swarf collector relative width n[1]. To determine the optimum value of n we construct the relationship P = f(n) (Fig. 1), from which it is obvious that P attains minimum value for n = 3.5.

The swarf collector height is determined from the condition of free passage of the largest swarf. Thus, when drilling brittle metals a conical spiral swarf is formed whose maximum length is

$$l_c = \frac{d}{2\sin\phi}$$

where ϕ is the half drill point angle. The swarf is thrown into the swarf collector by the centrifugal force acting at an angle ω equal to the drill helix angle (Fig. 2).

In this manner the swarf collector height is obtained as

$$h = h_1 + l_c = \frac{d}{2\sin\phi}(1 + \sin\omega \tan\omega).$$

Holes made in the swarf collector to allow for drill passage should be made with minimum clearance, their diameter not exceeding 1.1d.

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[1] Where n = b/d (d is drill diameter)

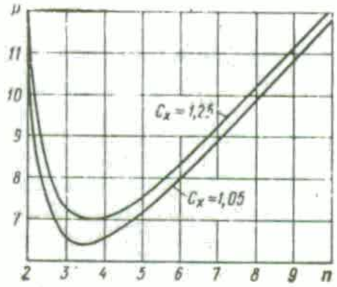

μ
11
10
9
8
7
2
3
4
5
6
7
8
9
n
$C_x = 1,25$
$C_x = 1,05$

Fig. 1

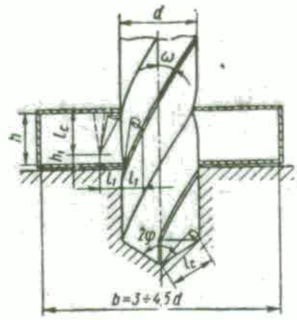

d
ω
h
l_c
h_1
l_1
l_1
2φ
l_c
$b = 3 \div 4,5d$

Fig. 2

1. KARLOV, R. F.

2. ADAPTIVE CONTROL IN DEEP HOLE DRILLING

3. MACHINES AND TOOLING, Vol. 45, No. 8, 1974, pp. 38-40

4. The problem of increasing the productivity of deep hole machining can be solved by employing adaptive control of the machine tool. Analysis of the disturbing factors (allowance, hardness, tool wear) which affect the hole machining process quality has led to the conclusion that they can be assessed by the radial cutting force component P_y. Accordingly, to reduce the effect of disturbing factors on the cutting process, it is necessary to stabilize the force P_y.

Since the measurement of P_y in the given case is difficult, one can use the fact that there exists a sufficiently strict relationship between the axial and radial cutting forces (at low cutting speeds which are typical for machining holes with $d \leq 50$ mm, the departure from this relationship does not exceed 8%). Therefore, stabilization of the axial force whose measurement is significantly easier ensures stabilization of the radial cutting force. As the controlled parameter, it is best to employ the feed.

A block diagram of an adaptive control system for machining deep holes is shown in Fig. 1. Information U_{so} about the initial feed per minute s_o comes from the reference element RE into the feed motor reference voltage unit VR_s, the information U_{vo} about the cutting speed v_o goes into the main motor MM voltage reference unit VR_v and information about the maximum permissible cutting force fluctuation amplitude goes into the limiter L.

The selected feed is constrained either by the maximum machine tool loading or by tool strength, i.e., the condition $s_o \leq s_{max}$ is satisfied. The cutting speed is selected such as to ensure optimality for the given value of s_o. At the same time the maximum permissible cutting force for the machine tool at optimum machining conditions is set.

The feed drive system FDS includes an intermediate amplifier IA, electromechanical amplifier EMA, drive motor DM, compensating element CE and tachogenerator TG. At the IA amplifier input there are algebraically summed, the reference voltage U_s, and voltages $U_{v.f}$ and $U_{p.f}$ from respectively the drive motor velocity feedback and EMA variable feedback.

Information about the cutting force is obtained from the force transducer FS, which can be of the magnetoelastic type, elastic with strain gauges, or current or power sensor. On two Model KZh1910 machines magnetoelastic sensors of the DNS type were

4. (Continued)

used and on one strain-gauge sensors. The sensor is placed in the tool slide and takes up the axial cutting force through a thrust bearing.

The signal U_P from the FS transducer which is proportional to the cutting force enters the limiter L, the memory M and the input of the variable coefficients block VC. When setting the cutting coefficients and setting up the machine tool, the signal entering VC is absent. After setting the machine tool for a given cutting force and switching on the adaptive system the memory M is disconnected from the FS transducer.

When the disturbances γ acting on the cutting process (CP block) change, a signal $U_{\Delta P} = U_{P_O} - U_P$ appears at the VC unit input which causes a change in the amplifier IA gain and accordingly in the entire system gain. The per minute feed rate s changes until the cutting force P_x is equal to the preset value P_o to an accuracy $\pm\Delta$. In this way the cutting force is stabilized.

The cutting force variation amplitude is limited by the limiter L. Its input receives signals proportional to the maximum permissible variation amplitude ΔP_m and to the cutting forces, namely the stipulated P_o and current $P_x(t)$. A signal is formed in L which is proportional to $\Delta P_m - [P_x(t) - P_o] = \Delta_m$, and at its output a signal is

$$\text{sign}\ \Delta_m = \begin{cases} 0 \text{ for } \Delta_m \geq 0; \\ 1 \text{ for } \Delta_m < 0, \end{cases}$$

which changes the VR_V setting of the main drive motor to control spindle speed. In this way, when the external disturbing factors influencing the cutting process change during machining, the parameters and the settings of the system controlling signal are changed.

Figures 2 and 3 show oscillograms of the transient process in the machine tool dynamic system with and without cutting force stabilization. As shown, external disturbances cause axial force changes if the stabilization is absent. With a stepped allowance variation, the cutting force changes in the same manner (Fig. 2(a)) but with a certain delay. The feed s is then practically constant. With stabilization (Fig. 2(b)) the axial force is practically constant which is obtained by changing the feed rate.

In the case of a sinusoidal allowance change (Fig. 3(a)) the cutting force and the feed change according to a sine curve. The feed change is delayed with respect to the cutting force change because of the inertia of the electric feed drive.

4. (Continued)

Therefore fluctuations of the cutting force with the control system acting are not entirely eliminated (Fig. 3(b)) but their amplitude is significantly reduced (from 30 to 5%). As a result the probability of cutting edge chipping and drill and boring head breakage is drastically reduced. However, at a certain spindle speed the fluctuation of cutting force and feed can be in counterphase (unstable system performance). The cutting force fluctuation amplitude is limited by the limiter L.

Accuracy tests were also performed; analysis of their results indicates that through the use of the described system the dimensional error is reduced 2-4 times.

Tests results have shown the high effectiveness of axial force stabilization systems for deep hole drilling machines. The axial force fluctuations are reduced 4-5 times, machining accuracy improves 2-4 times and the cutting process is performed at maximum permissible force conditions. The adaptive system is best suited for machine tools which have electric d.c. drive motors with wide range variable speed. In that case there is no need for significant changes in machine tool kinematics.

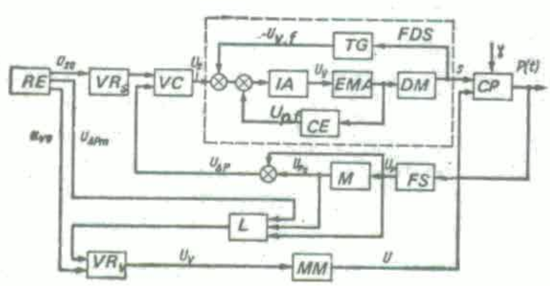


Fig. 1.
Block diagram of an adaptive control system for machining deep holes.

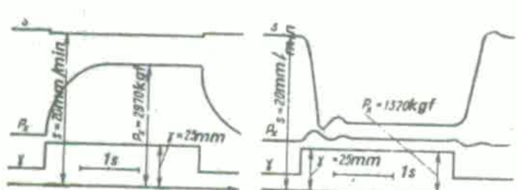


Fig. 2.
Transient process oscillograms for step changes in machining allowance: (a), without cutting force stabilization; (b), with stabilization.

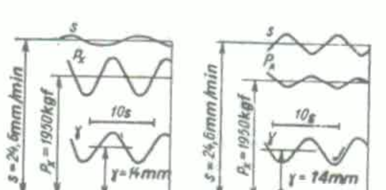


Fig. 3.
Transient process oscillograms with sinusoidal allowance variations: (a) and (b), the same as in Fig. 2.

1. YUDOVIN, L. G., et al

2. COOLING TWIST DRILLS IN DEEP DRILLING JOBS

3. MACHINES & TOOLING, Vol. 45, No. 9, 1974, pp. 45-46

4. A study of the pumping effect of helical flutes was undertaken in a lathe using the special rig shown in Fig. 1. In the predrilled hole of blank 1 is mounted rubber tube 2 connected to glass tube 3. A second glass tube 4 is connected to chamber 5, through which pass arbor 6 and drill 7. Between the arbor and chamber is seal 8, and between the endface of the blank and the chamber is packing 9. The drill is introduced to the hole to a depth ℓ, and the entire system is filled with a 5% oil emulsion.

With the drill stationary, the coolant is at the same level in tubes 3 and 4, but with the drill rotating there is a level difference Δh, which characterizes the pumping effect of the drill flutes. Fig. 2 shows graphs of Δh plotted against and spindle speed n (rev/min); it will be seen that with increasing n and ℓ, the pumping effect of the flutes increases. For example, with $n = 1000$rev/min and $\ell = 250$mm, $\Delta h = 100$mm of water column.

Tests were also performed to determine the penetration of the coolant to the cutting zone (allowing for the effect of the swarf). Blanks 250mm long were through-drilled with worm drills ($d = 14$mm, $\omega = 60°$). The required coolant pressure was obtained by maintaining a given fluid level in tube 4 (Fig. 1) with tube 2 removed. In all the tests, when the drill emerged from the hole a jet of vapour came with it, then fluid either flowed out or did not flow out, depending on the pressure and speed. It follows from the tests, the results of which are given in the Table, that to ensure that the cutting fluid reaches the cutting zone a considerable pressure is required. For example, with $n = 100$rev/min, the fluid pressure must be more than 500mm of water column.

It is known that when twist drills with internal coolant-delivery channels are used, drill life depends on pressure. Because long twist drills do not have these channels, in the tests the coolant was delivered to the cutting zone as a result of static pressure. The criterion was the drill cutting edge temperature; this was selected because of the relationship between temperature and life.

At the same time, cutting-zone temperature was determined with thermocouples built into the blank. The temperature of the blank was measured at the point of the hot junction, and the drill temperature was determined as the mean cutting edge temperature over the entire length from this point to the drill periphery.

4. (Continued)

The relationship between temperature and fluid pressure was determined by drilling steel 45 with 14mm diameter drills with a feed of s = 0.11mm/rev and speeds of n_1 = 360 and n_2 = 500rev/min. The fluid pressure (5% emulsion) was 0.02-12kgf/cm^2.

The relationship between temperature and pressure was determined for both the drill and the blank using the equation $\theta = \theta_0 + ae^{bp}$, where θ_0 is the temperature with the optimum fluid pressure, p the pressure of the fluid and a and b are constants.

Values of the constants were determined as the mean for the given speeds: with n = 360rev/min for drills

$\theta_c = 258.8 + 85.4e^{-0.39p}$; for blanks $\theta_b = 164.1 - 43.4e^{-0.59p}$. With n = 500rev/min $\theta_c = 311.9 + 32.7e^{-0.58p}$ and $\theta_b = 123.5 - 53.1e^{-0.46p}$.

Graphs for n = 500rev/min are shown in Fig. 3. The rise in temperature of the blank with increasing pressure can be put down to the fact that the fluid gets closer to the contact point, and this facilitates greater heat transfer from the tool and chip to the blank.

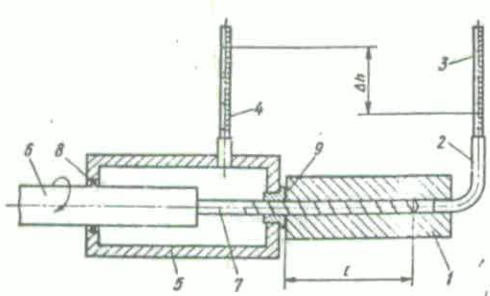


Fig. 1.
Rig for determining pumping effect of drill flutes.

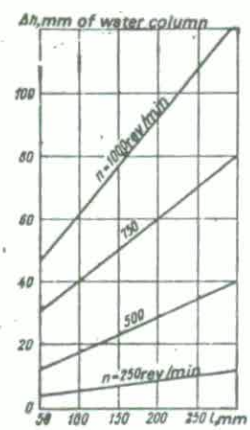


Fig. 2.
Δh plotted against l and n.

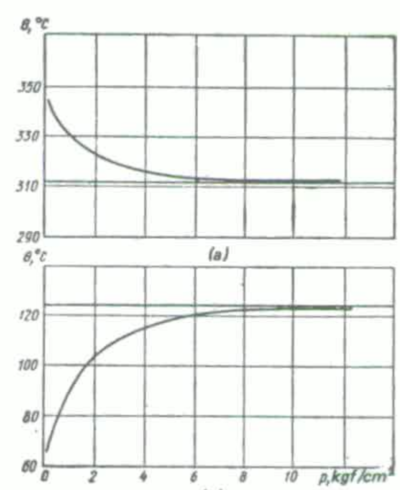


Fig. 3.
Drill temperature (a) and blank temperature (b) plotted against coolant pressure.

h (mm of water column)	n, (rev/min) 360	500	750	1000
65	–	–	–	–
190	–	–	–	–
290	+	–	–	–
390	+	+	–	–
500	+	+	+	–
600	+	+	+	+

Note: A plus sign indicates that coolant flows out; a minus sign indicates that coolant does not flow out.

1. SCHNITZLER, H.

2. BOHREN MIT KONSTANTER KURZER AUSKRAGLÄNGE
(Drilling with a Constant Length Drill)

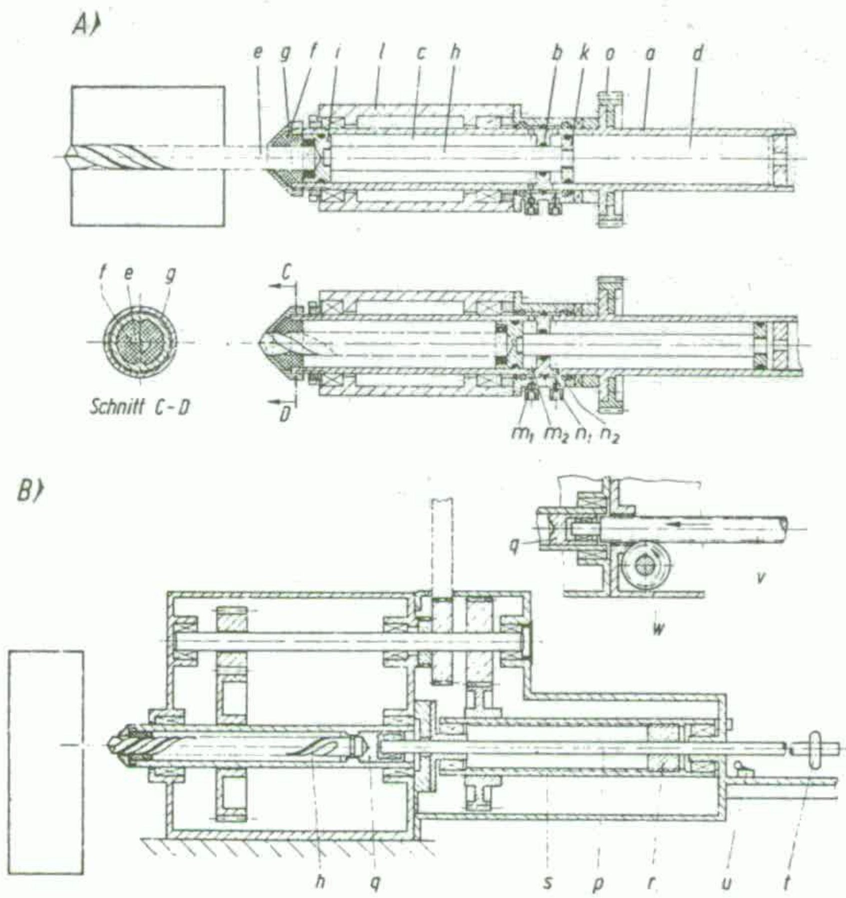
3. WERKSTATT UND BETREIB, 1974, Vol. 107, No. 3, pp. 175-176

4. In the past, the research report stated that the length of drill greatly affects the torsional vibration. If a drill is shortened, by chucking, to the surface of the workpiece being drilled, the torsional vibration and breaking force can be increased by 64 times, and consequently, the drill life increases by 3 6 times.

After extensive investigation, it was found that a shortened twist drill enables the use of increased feed rate by three to six times and also the drilling length for a drill life can be extended three to six times.

There are several developments for an adapter, which will provide many advantages.

Fig. 1a shows two different designs, which were registered as patents. The top figure indicated hydraulic systems for forward and backward motion, while the bottom shows the mechanical system for the movement.



1. DRAGHICI, G., AND PALTANEA, C.

2. PROGRAMMIERTE BERECHNUNG DER SCHNITTDATEN BEIM BOHREN MIT MEHRSPINDEL-BOHRKÖPFEN (Programmed Calculations of Drilling Conditions in Multi-Spindle Drilling Operations)

3. WERKSTATT UND BETRIEB, Vol. 109, No. 2, pp. 111-116, 1974

4. Since drilling operations with multiple-spindle drilling heads is spreading into mass and larger size manufacturing, an exact scientific calculation of the operation parameters is desired.

   The question - how should the drill be replaced, whether simultaneously or individually, when the drill reaches its tool life - is not clearly answered.

   If all the drills are simultaneously replaced, the idle time of the machine tools will be greatly shortened. However, in this case, the existence of the possibility that not all drills reach their life at the same time does neither make this practical nor economical.

   In this paper, the calculation methods to the conditions for the simultaneous replacement is described. The solution is illustrated with simple graphs, in which maximum spindle rotation vs feed rate in connection with various factors is shown in Fig. 1.

   The optimum condition for the minimum cost is indicated as point P which is obtained when the spindle rotation is n_1 = 2240 rev/min and the feed rate s_1 = 0.08 mm/rev.

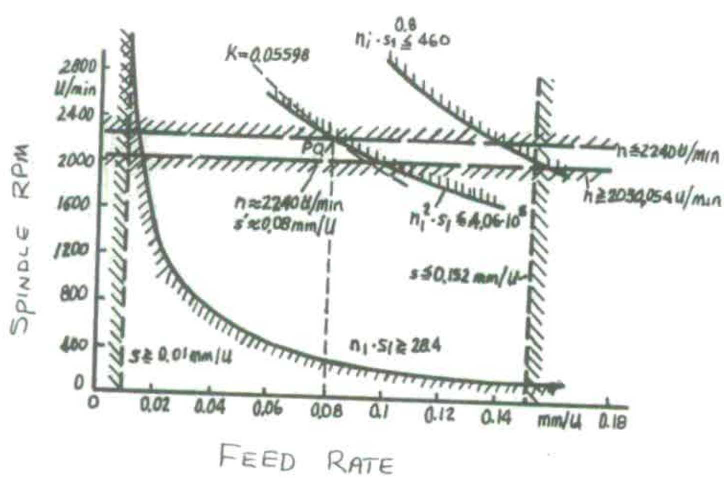


Fig. 1

1. ANONYMOUS

2. THE EFFECT OF SULFUR AND PHOSPHORUS CONTENTS IN STEEL AND THE MACHINE USED ON DRILL LIFE

3. JOURNAL OF THE JAPAN SOCIETY OF PRECISION ENGINEERING, Vol. 40, No. 10, 1974, pp. 13-18.

4. The paper deals with the effect of sulfur and phosphorus contents in steels on the drill life, drilling resistance, oversize of holes and chip formation. Also discussed is the cause of the variation of the test results at different laboratories. The conclusions are summarized as follows:

(1) The most reliable drill life models are statistically found as $L = \exp\{b_0\}(100S)^{b_1}(100P)^{b_2}V^{b_3}$ for 0.45% carbon steels (JIS S45C), and $L = \exp\{b_0'\}(100S)^{b_1'}V^{b_2'}$ for low-carbon chrome-molybdenum steels (JIS SCM 22).

(2) As the sulfur content is increased, the drill life is increased, the drilling resistance decreased and the chip thickness decreased. The phosphorus content has the inverse effect. The both have almost no effect on the oversize of holes.

(3) When the material drilled produces brittle chips, the drill life is increased because of the lower resistance and temperature, and vice versa.

(4) The large differences in the drill life and drilling resistance between the test results obtained at the participant laboratories are found to be attributed to the difference in the properties, especially the rotating accuracy of the spindle, of the machines used.

1. M. KANAI

2. A FUNDAMENTAL STUDY ON DRILLING (First Report, On the Amount of Regrinding Drills)

3. TRANSACTIONS OF THE JAPAN SOCIETY OF MECHANICAL ENGINEERS, Vol. 40, No. 330, pp. 600-607, 1974

4. During the resharpening of a drill, the amount of material that should be removed from the worn part must be considered, as well as the kind of wear and failure that would most affect the drill life. On the other hand, the determination of the volume that should be removed by grinding for the resharpening must be based on the most economical volume during removing.

Drill: HSS (JIS SKH 8) straight shank, 10 mm dia., 30° helix angle, point angle 135°, relief angle 10°

Work: Carbon tool steel (JIS SK7) Annealed, 100 x 100 mm section, HB 170, 3 mm of skin was removed.

The wear pattern of the drill is shown in Fig. 1.

W_e: Chisel edge wear

W_f: Flank wear

W_c: Corner wear (conjunction between flank and margin)

W_m: Longest length from corner to feed mark appeared on the margin

W_m': Longest width of margin wear.

The results of comparison between newly purchased drills and resharpened drill are shown in Fig. 2. As shown in the figure, newly purchased drills last longer than resharpened drills. Among the resharpened drills, those which had large volumes removed showed an advantage in drill life.

The drills, when they reached a certain drill life, experienced exceedingly high temperatures. Therefore, such drills should have a significant decrease in hardness. Fig. 3 indicates that the hardness decreased only in the range of 0.5~0.6 mm from end of lip to center. Through these investigations, the relationship between drill life vs removing volume in drills can be expressed as shown in Fig. 4. This figure indicates that when a certain range of grinding volume is exceeded, the removed volume has no effect on the drill life.

The economical considerations - total cost of a drill until drill is unable to be resharpened (C_t) and the total sum of drill life until drill is unable to be resharpened (L_t) are presented in Fig. 5.

4. (Continued)

From the above results, the drill cost for a unit drill life (C_b) vs volume for resharpening (C_t), can be determined as indicated in Fig. 6.

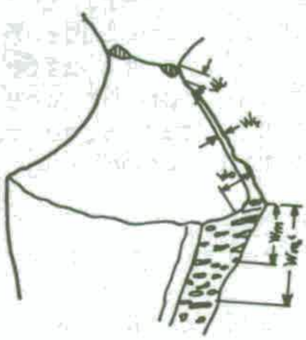


Fig. 1

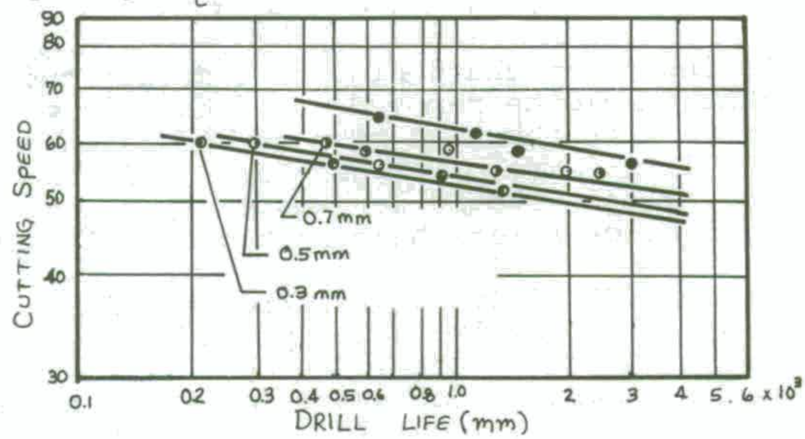


Fig. 2

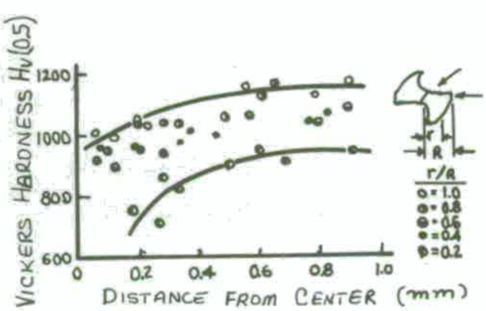


Fig. 3

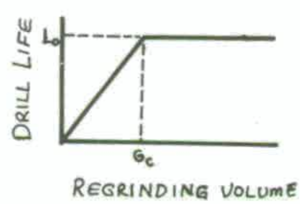


Fig. 4

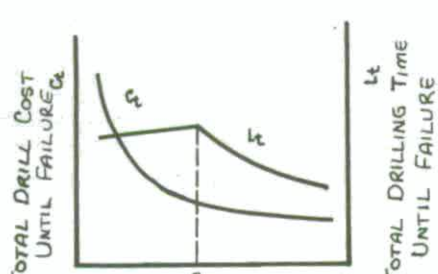


Fig. 5

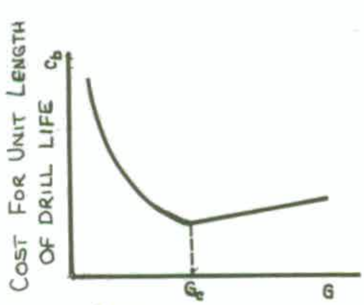


Fig. 6

1. M. KANAI

2. A FUNDAMENTAL STUDY ON DRILLING (Second Report, On the Variation of Drill Life - 1)

3. TRANSACTIONS OF THE JAPAN SOCIETY OF MECHANICAL ENGINEERS, Vol. 41, No. 346, pp. 1926-1932, 1975

4. As Galloway already pointed out, drill life varies under the same drilling conditions which are caused by various factors. The cause of the variation in drill life can be classified in two categories; one can be caused by the systematical influences and the other caused from the uncertainties or some irregularity. As workpieces, three different types of work materials, such as SUS 403-HT (HB 172), SNCM8-A (HB 208) and SK7-A (HB 170) were chosen. For each work material, the drill life test was repeated 25 times. Complete failure was defined as a drill life criterion. The results were plotted as a cumulative percentage connected with drill life on the three different coordinates:

   Fig. 1. Weibull cumulative frequency

   Fig. 2. Normal cumulative frequency

   Fig. 3. Log-normal cumulative frequency

   If the helix angle increases, the rake angle will increase and consequently, the drill life is expected to increase. Fig. 4 presents the investigation results of the effect the helix angle had on the drilling speed for drilling lengths of 1000m (V_L = 1000). This was carried out on all four different work materials. From these results, it can be seen that the helix angle tends to be smaller for maximum drill life, as the workpiece becomes harder.

   The point angle on a standard twist drill is 118 degrees, however, depending on the work material, the point angle varies for a longer drill life.

   Fig. 5 presents the effect of the point angle on the drill life for four different work materials. The effect of the relief angle on the drill life was also determined and is shown in Fig. 6.

   Galloway presented in his paper, results that showed the drill life decreasing as relative lip height was increasing. However, he conducted his experiments with only one work material. The author concluded the relationship between relative lip height and drill life for four different work materials, which are presented in Fig. 7.

4. (Continued)

It was reported there is some effect of drill length on the drill life. The results of the tests are described in Fig. 8.

Generally, at increased feed rates, drill life decreases and it can be expressed as

$$(VL)^n f^a = c$$

where f = feed rate mm/rev and a and c are constants. It was interesting to determine the range of feed rates, which could be applied to the above relationship. Fig. 9 shows these results, in which it can be realized that the drill life decreases linearly as feed rate increases above 0.20 mm/rev. while below this point, it showed a reverse trend.

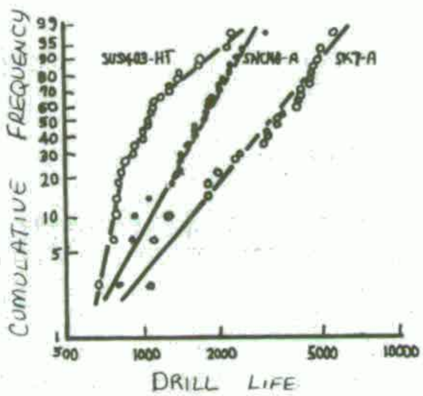


Fig. 1

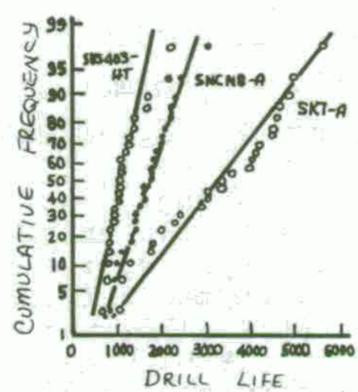


Fig. 2

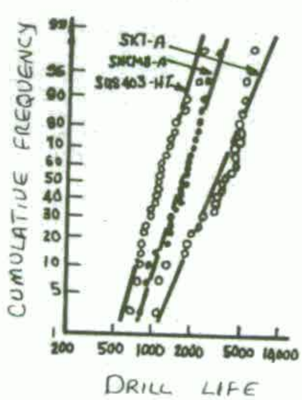


Fig. 3

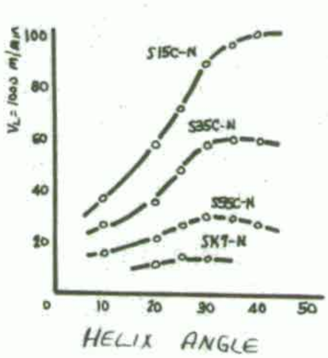


Fig. 4

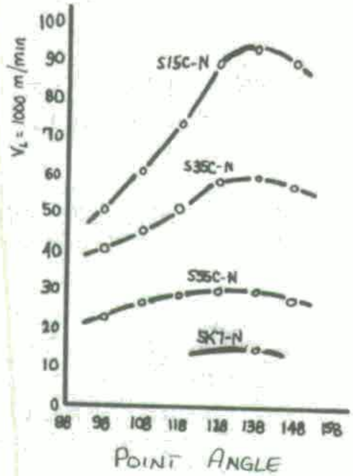


Fig. 5

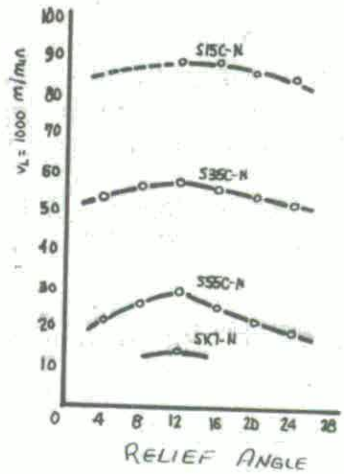


Fig. 6

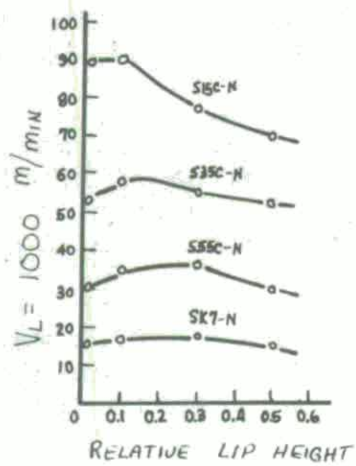


Fig. 7

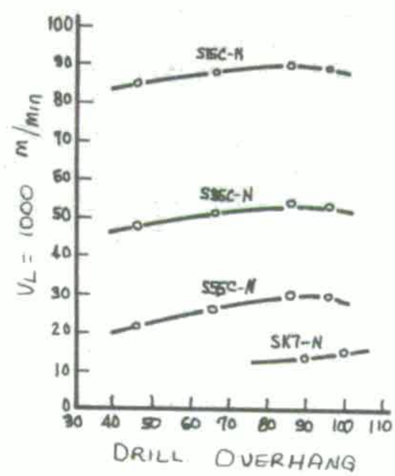


Fig. 8

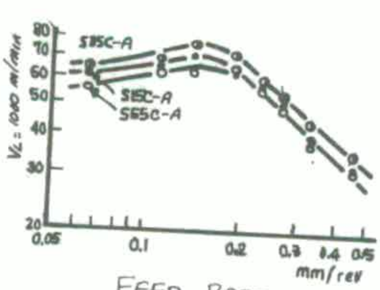


Fig. 9

1. OBA, J.

2. THE FUNDAMENTALS ON THE STRENGTH OF THE DRILL (Part 1, The Torsional Stress on the Cross Section of the Drill Studied by Means of Soap Film Analogy)

3. TRANSACTIONS OF THE JAPAN SOCIETY OF MECHANICAL ENGINEERS, Vol. 41, No. 347, pp. 1965-1974, 1975

4. Even though a number of research reports on drill performance are available, the research on the strength of twist drills is rather limited. In this paper, an experimental study on the strength under torsion, by means of soap film analogy, is described. The advantages of this method is that the maximum shear stress, the relative magnitude of shear stress and its location, when the cross section of the drill is twisted by applying torsional forces, can be easily evaluated. This is especially true for a complicated cross section like a twist drill, which can be examined by photography soap film and the result of which is highly appraised.

   The ratio of web thickness, b, to drill dia., D, is varied from 0.05 to 0.5. The shear stress function of b/D is shown in Fig. 1. The maximum stress is generated at point X, the stresses at point A and C demonstrated a reverse trend towards the increased b/D ratio.

   The maximum stress is generated at point X, which moves depending on the b/D ratio. The angle α is remarkably decreased at a b/D ratio of 20, which is shown in Fig. 2.

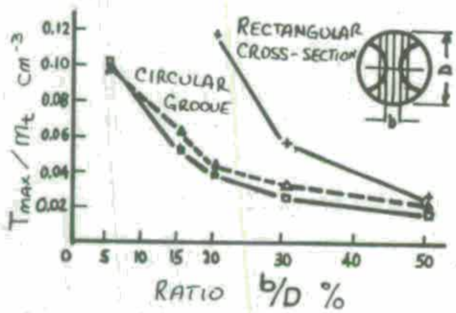

RECTANGULAR
CROSS-SECTION
CIRCULAR
GROOVE
D
b
0.12
0.10
0.08
0.06
0.04
0.02
0
5
10
15
20
30
40
50
RATIO b/D %

Fig. 1

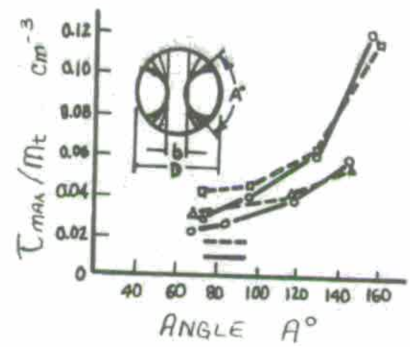

A°
b
D
0.12
0.10
0.08
0.06
0.04
0.02
0
40
60
80
100
120
140
160
ANGLE A°

Fig. 2

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This report brings together in one volume the vast information on drills and drilling processes published in numerous journals and technical papers. A review of more than 800 articles was conducted, the result being a collection of 271 of the most valuable articles in the field of drilling from worldwide publications dated 1896 to present. A brief abstract of each article is given along with important illustrations and tables. This systematic survey of literature on twist drills and drilling will be useful to those who wish to study the essential research results and stages of development in this field.

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